CONCISE
HUMAN HISTOLOGY
FOR MEDICAL STUDENTS

R. Prasad

CONCISE HUMAN HISTOLOGY

SECOND EDITION

CONCISE
HUMAN HISTOLOGY
FOR MEDICAL STUDENTS

R. PRASAD, B.SC., M.B.B.S., M.S.
Professor & Head, Department of Anatomy,
S. K. Medical College, Muzaffarpur

VIJOYA PUBLISHING HOUSE
106, Vivekananda Road,
Calcutta-700006.

Published by Biswanath Bhattacharyya
Vijoya Publishing House
106, Vivekananda Road,
Calcutta-700006.

© Reserved by R. Prasad.

First Edition, January, 1977
Second enlarged Edition, January, 1988

Price Rs. 22.50 only

Acc no - 16891

Printed by Hara Lal Bardhan
Bardhan Press
8/4A, Kashi Ghose Lane,
Calcutta-700006

To My Wife Shanti

Rieari 4955 94

PREFACE TO THE SECOND EDITION

The book has been thoroughly revised and amplified in several places. I am confident that this book should be more than adequate for medical students.

The second edition has been published by Messrs Vijoya Publishing House, Calcutta. I would like to thank the publishers for their helpful cooperation.

Muzaffarpur
January, 1988

R. Prasad

PREFACE TO THE FIRST EDITION

The primary aim of this book is to give the medical students the essential facts concerning the tissues and organs of the body in a clear and concise manner. Histology has been presented in a possible minimal number of pages. For the sake of simplicity and clarity of style many unnecessary details have been omitted but without the sacrifice of any material which is essential to the proper understanding of histology.

The illustrations have been kept simple and are for the most part diagramatic in form, all of which can be easily drawn by any student. The last two chapters are mainly meant for intermediate students appearing at the examination. Chapter 17 points out in brief how to identify slides. Chapter 18 contains selected questions which are usually asked in the examination.

It is a pleasure to acknowledge the valued assistance of colleagues and friends who have offered helpful suggestions. I should like to express my appreciation and thanks to Mr. B. N. Rama, Mr S. K. Choudhury and Mr. S. K. Jain for their help. I owe, finally to my wife and children for their unfailing patience and forbearance.

For the text as it now stands, I alone am responsible. Any criticism which will improve the book as a teaching medium will be gratefully acknowledged. If in some cases there is any error, I crave indulgence, for if the flesh was fallible in this respect, at least the spirit was anxious to do the right thing.

Ranchi
January. 1977

R. Prasad

CONTENTS

THE TISSUES OF THE BODY   Page

1. Histology as a Subject. ... 1
2. The Cell. ... 6
   Cell Division ... 12
3. Epithelial Tissue and Glands ... 16
4. Connective Tissues ... 27
   I Connective Tissue Proper. ... 27
   II Cartilage. ... 32
   III Bone. ... 35
   IV Blood. ... 40
5. Muscular Tissue ... 45
6. Nervous Tissue. ... 50

ORGANS AND SYSTEMS

7. Cardiovascular System. ... 65
8. Lymphatic System. ... 71
   Lymphoid Organs. ... 72
9. Endocrine Glands ... 79
10. The Integumentary System. ... 88
11. Respiratory System ... 95
12. The Digestive System. ... 101
    Glands associated with Digestive Tract. ... 115
13. The Urinary System. ... 124
14. Male Reproductive System. ... 132
15. Female Reproductive System. ... 142
16. Special Sense Organs. ... 152
17. Identification of Slides. ... 160
18. Viva Questions. ... 168
    INDEX ... 175

1 Histology as a Subject

Histology (Microscopic Anatomy) is the study of tissues of the body, and deals with those minute structures that are beyond the reach of naked eye. In the strict sense, histology is the study of tissues, but generally speaking it includes the study of cells (cytology), and organs (organology). Structure and function are so correlated that a sound knowledge of histology is a prerequisite for the proper understanding of normal physiology.

Living cells or tissues are translucent or even transparent, and their constituent parts differ very little from one another in refractive index, so that there is hardly any visible contrast between them. More so, the refractive index of most cells are very close to the aqueous media in which they are usually examined. As such living cells appear structureless to a large extent. Therefore, fixed tissues are treated with various dyes to create colour contrast which reveals structures to great advantage. In histology we never see tissues as they are in situ, but magnified and usually highly coloured. Cells are seen much larger than normal, usually with blue nuclei and pink cytoplasm.

METHODS OF EXAMINATION OF TISSUES

A. Histological Methods (Most commonly used).

Preparation of a tissue for study with light Microscope involves :

1. *Obtaining the tissues* : Small pieces about 5 mm. × 5 mm. are cut immediately after death or at operation.

2. *Fixation* : The tissues are fixed usually in 10% formo-saline for 12 to 24 hours. Fixation prevents post-mortem degenerative changes and hardens the tissues.

Decalcification (Removal of calcium salts) : After fixation tissues like bones and teeth are decalcified by weak acids, so that they become soft and section cutting is possible.

3. *Dehydration and clearing* : Dehydration is removal of water from the tissues by passing through ascending grades of alcohol.

After complete dehydration, the tissues are cleared with methyl benzoate. Tissues can be preserved in methyl benzoate for years.

4. *Embedding and Block making* in paraffin wax. Prior to embedding, tissues are treated with benzene for 2 hours, and then cooked in molten paraffin at 55° to 60°C for 2½ hours. At the end tissues are put in rectangular blocks of molten paraffin, which subsequently solidifies.

5. *Section cutting* : Thin sections (5 to 7 $_{\mu}$) are cut on a rotary microtome. The sections are then affixed to the albuminised slide.

6. *Staining and Mounting* : Usually the sections are stained with haematoxylin and eosin (H & E staining), the procedure of which is given below :

(i) Deparaffinise (Removal of paraffin) by a wax solvent e.g., xylol for 1 to 2 minutes.

(ii) Pass the slide successively through absolute alcohol, 90%, 70% and 50% of alcohol, each for one minute, and then put in distilled water.

(iii) Stain in haematoxylin for 5 minutes.

(iv) Rinse in distilled water, differentiate in ½% Hcl (just a dip), and then put in running tap water for 5 minutes. The alkalinity of tap water helps in blueing the section.

(v) Rinse in distilled water ; pass through 50% and 70% of alcohol for one minute each.

(vi) Stain in eosin for ½ to 1 minute.

(vii) Dehydrate by passing through 90% and absolute alcohol.

(viii) Clear in xylol for 2 minutes to remove absolute alcohol.

(ix) *Mounting*—Cover with a transparent mounting media e.g., canada balsam or DPX, and finally put a cover slip.

(x) *Ringing*—After mounting, a solution of lac or nail polish is applied around the margins of coverslip.

Haematoxylin is a basic dye, while eosin is an acidic dye. Nuclei are basophilic and have affinity for basic dyes like haematoxylin which colours them blue. Most cytoplasm and inter-cellular substances are acidophilic and are stained red with acid dyes e.g., eosin.

Staining of Blood Film :

Cover the dried blood film with Leishman's stain. After one minute dilute the stain with equal volume of distilled water. Leave for 7 to 10 minutes. Wash the slide well with distilled water. Dry in air, and examine under oil immersion lens.

B. Special Methods :

Histochemistry involves special fixations and special stainings to localize chemical substances in tissue sections, e.g., PAS reaction for mucoproteins and mucopolysaccharides ; Feulgen reaction for DNA ; Prussian blue reaction for iron.

Autoradiography determines the metabolic path of labelled radioactive isotopes in tissue sections e.g., labelled iodine in thyroid gland.

Maceration, Microincineration, Centrifuging, X-ray diffraction, Microspectroscopy and various other methods are employed.

EXAMINATION OF LIVING TISSUES

1. *Direct observation* of blood or teased preparation in normal saline.

2. *Supravital staining* : Certain dyes colour living cells in fluid media e.g., Janus green to stain mitochondria.

3. *Vital staining* : Tissues are stained by introducing inert, non-toxic dye (e.g., India ink, trypan blue) solution into the living organism. The dye is taken up by the cells of reticuloendothelial system.

MICROSCOPES

Microscope is an instrument for the study of minute details of objects.

Light (Optical) Microscope (LM)

Light microscope is a system of lenses and its sole purpose is to enlarge (magnify) minute details.

(A) Parts :

1. *Base.*
2. *Stage to keep slides.*
3. *Sub stage arrangement* of mirror, diaphragm and condenser lens.
4. *Arm holding the Body tube.* The body tube has an *eye piece* at its upper end, and a number of objectives (low power, high power and oil immersion objectives) on a revolving nose piece at the lower end.
5. *Adjustment System.* There are two adjustments, *crude* and *fine,* to move the body tube (or the stage) up and down.

(B) Basic principles in the use of Microscope :

1. *Slide is kept on the stage with the cover slip facing upwards.*

2. To get an optimum amount of light :

(a) *Mirror* : (To direct the light properly). The type of mirror used depends on the **source of light.**

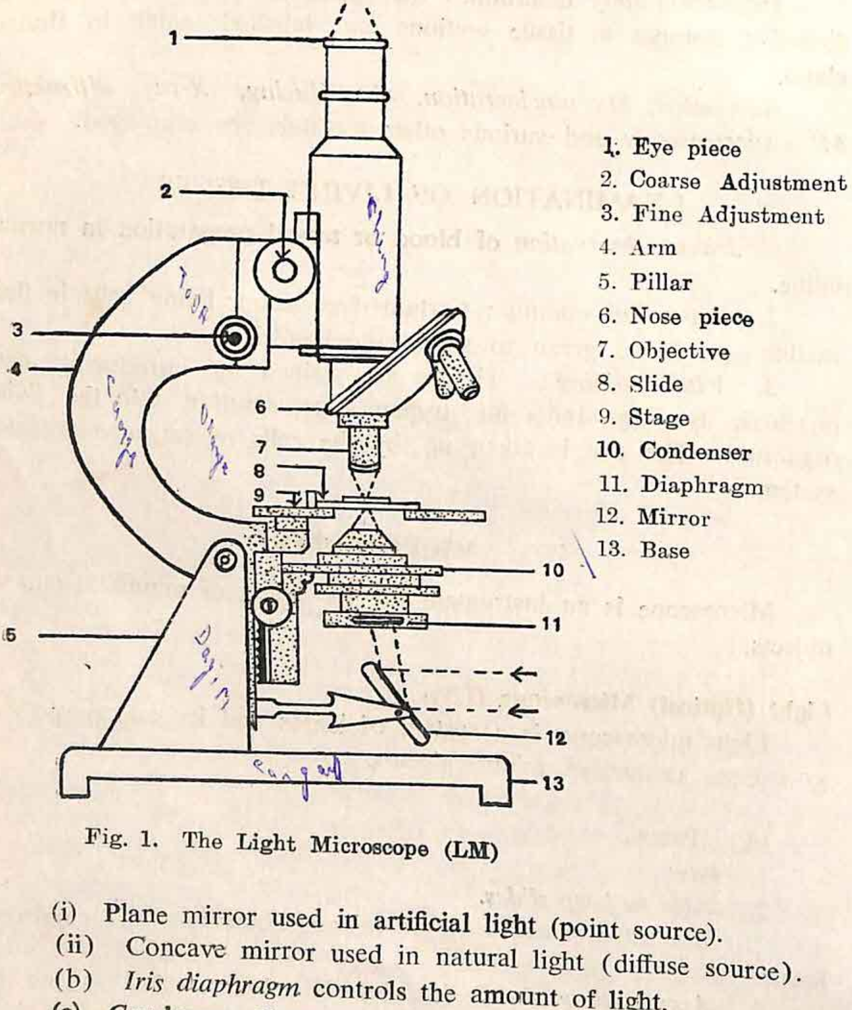


Fig. 1. The Light Microscope (LM)

(i) Plane mirror used in artificial light (point source).

(ii) Concave mirror used in natural light (diffuse source).

(b) *Iris diaphragm* controls the amount of light.

(c) *Condenser*—Converges the nearly parallel beam of light that comes from the mirror below, so that a cone of light emerges from its upper surface. Condenser lens controls the intensity of light; usually it is kept up with high power objective, and kept down with low power objective.

3. *To focus the object* : Both crude and fine adjustments are used while focussing in low power. Use ony fine adjustment in high power.

4. Magnification is determined by multiplying eye piece number with objective number.

Phase Contrast and interference Microscopes

These microscopes create contrast by optical means and help in the study of livng cells and unstained tissues.

Fluorescence Microscope

It reveals fluorescent materials in cells under ultraviolet radiation.

Polarising Microscope

Detects the presence of **birefringence** (double refraction) in objects.

Electron Microscope (EM)

In *electron Microscope* high speed electron beams replace light ; a system of electromagnetic fields replace lens system. The final image is projected on a fluorescent screen and photographed. EM has great resolving power and magnifies 100,000 times or more. *Scanning election microscopy* is gaining widespread recognition in conveying three dimensional concepts.

EM has opened new horizons that were at best dimly perceived before, yet the maze of fine details revealed by it can only be understood if one has a sound knowledge of light microscopic histology. Thus the study of prepared slides of killed, dehydrated and stained tissues are of great value even today.

UNITS OF MEASUREMENT USED IN HISTOLOGY

1 micrometre (μm) or micron (μ) =1/1000 part of a mm.

1 millimicron (mμ) or nanometre (nm)=1/1000 part of micron.

1 Angstrom (Å) (unit of E M) =1/10 of a millimicron or 1/10,000 part of a micron.

2 The Cell

The cell is the structural and functional unit of the body.

Shape

Most cells are *polyhedral*. Free cells are *spherical* or *oval*, e.g. leucocytes. Some cells are specialized to carry specific functions and their shape is greatly altered e.g., neurons, muscle cells.

Size

Cells on an average vary between 10μ to 20μ ; small lymphocytes are about 6.5μ ; human ova about 150μ ; large nerve cells 120μ to 160μ. Skeletal muscle fibres may be even 30 cm. long or more.

Parts of a Cell

1. CELL MEMBRANE ;
2. CYTOPLASM ;
3. NUCLEUS.

1. Cell Membrane

All cells are enclosed by a thin, tough and elastic limiting membrane called *plasmalemma* or *cell membrane*.

With LM usually it cannot be seen as it is very thin.

Chemically it is a lipoprotein complex and consists of a bimolecular layer of lipid with a layer of protein attached on each of its surfaces.

With EM it is about 80 Å thick and is trilaminar consisting of two parallel dense layers each 25 Å, separated by a light intermediate layer 30 Å. The dense layer is protein and the light intermediate layer is lipid. This trilaminar structure is referred to as the *unit membrane* and is common to all cells.

Functions : The cell membrane is a semipermeable membrane and takes active part in *phagocytosis*,* *pinocytosis*† and *particle ejection.*

2. Cytoplasm

The cytoplasm is the part of the cell lying between the cell membrane and the nucleus. It consists of a watery solution of salts, proteins, carbohydrates, lipids and ribonucleic acid.

Structurally the cytoplasm contains : A. Organelles, B. Inclusions.

A. Organelles

Organelles are minute living structures (little factories) of the cytoplasm having specific functions in the cell metabolism. These are mitochondria, endoplasmic reticulum, ribosomes, Golgi complex, cytocentrum, lysosomes, microbodies, microtubules and filaments.

1. Mitochondria : *With LM* after staining supravitally by Janus green B mitochondria appear as granules .5 to 2μ or as filaments 5μ long.

With EM they look cylindrical and are bounded by double membranes. The inner membrane is thrown into a series of internal folds called *cristae*. The interior of mitochondria is filled with mitochondrial matrix which contains a little RNA and DNA besides enzymes.

Function : Mitochondria are mobile power plants and supply energy for numerous chemical reactions. Each mitochondrion is a minute unit of enzyme activity. Enzymes concerned with cell respiration are located in the membranes and cristae, and are responsible for the synthesis of A.T.P. from A.D.P. Enzymes of Kreb's citric acid cycle are present in the mitochondrial matrix.

2. Endoplasmic Reticulum and Ribosomes : *With LM* endoplasmic reticulum appears as deep blue staining particles usually concentrated in the basal part of the cells e.g., pancreatic cells.

With EM it appears as a rich network of membrane bound flattened tubules and sacs.

Types : (a) Granular (rough), (b) Agranular (smooth).

---

* *Phagocytosis* is a process by which some cell engulf particulate matters including bacteria.

† *Pinocytosis* is a process by which liquid droplets are taken into the cell from their external environment by the formation of vesicles from the cell membrane.

(a) *Granular endoplasmic reticulum*: In section it appears as double black lines; the outer surfaces are studded with ribosome granules (membrane bound organelle rich in RNA). Ribosomes lie free in the cytoplasm as well. Attached Ribosome granules are the sites of protein synthesis to be secreted by the cell. Free ribosomes in the cytoplasm synthesize protein for the utilization of the cell.

(b) *Agranular endoplasmic reticulum*: These are devoid of ribosome granules and are present in steroid secreting cells of suprarenal cortex, testis and ovaries. They are concerned with steroid synthesis, lipid metabolism and detoxication process.

3. **Golgi Complex:** *LM*: When stained by silver salts, the Golgi complex appears as anastomosing network of threads of varying sizes. It is supranuclear in position in secreting glandular cells.

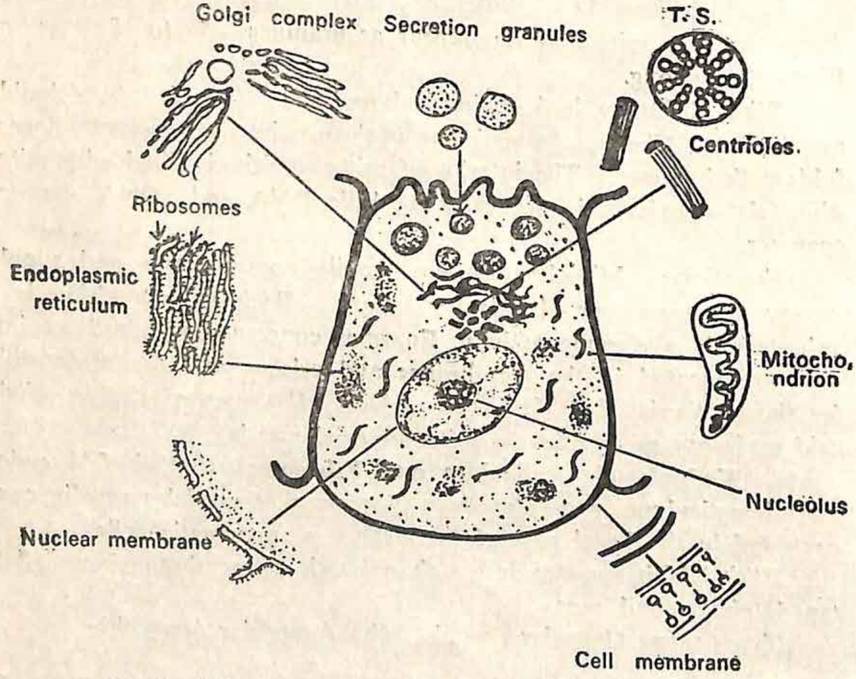


Fig. 2. Cell: The central diagram as in LM, the peripheral structures as in EM

EM: It appears as stacks of curved flattened saccules that are often expanded at their ends. These sets are associated with small and large membrane bound vesicles.

Function: Protein synthesized in endoplasmic reticulum migrates to Golgi complex, where it is stored and condensed into granular form for secretion.

4. Cytocentrum (centrosphere): *LM*: The cytocentrum is a small area of condensed cytoplasm in the supranuclear position and contains one or two minute dots called *centrioles*.

EM: Centrioles are two hollow cylindrical structures set at right angles to each other. In T. S. a centriole has a circular outline and its wall is composed of nine groups of longitudinally arranged tubules ; each group consisting of three inter connected tubules.

Function: (i) centrioles replicate and form the spindle during cell division. (ii) In ciliated cells it forms basal corpuscles of cilia.

5. Lysosomes, Microbodies: These membrane bound vesicles contain various hydrolytic enzymes and are concerned with the breakdown of phagocytosed exogenous materials. After death the cells begin to 'self destruct' by *autolysis,* following release of these enzymes.

6. Microtubules, Filaments: *Microtubules* are long slender tubules, *filaments* are Slender threads. Both these organelles form internal supporting framework of the cells. Microtubules also help in cell division by forming spindle fibres. In epithelial cells bundles of filaments form *tonofibrils.*

B INCLUSIONS

Inclusions comprise lifeless metabolic products and are temporarily a part of the cell. They include secretory granules, glycogen and lipids, pigments (e.g., melanin, hemosiderin, lipofuscin), and crystals (e.g., in interstitial cells of testis).

3. Nucleus

The nucleus is an essential component of nearly all cells, (except mature RBC) and takes a deep basic stain.

Shape: It is usually spherical; oval in columnar cells; flattened in squamous cells ; rod shaped in smooth muscle cells.

Size: Size varies and bears a close relationship with the volume of the cytoplasm.

Position: It is central in most cells, basal in mucoid cells, peripheral in skeletal muscle fibres.

Number: Most cells have only one nucleus. Occasionally binucleate cells are found in urinary bladder epithelium, liver and cardiac muscle. Skeletal muscle fibres are multinucleated.

Component Parts of Nucleus

The interphase nucleus (i.e., nucleus not in the process of division) has 4 parts : 1. Nuclear membrane, 2. Nuclear sap, 3. Nucleolus and 4. Chromatin.

1. Nuclear membrane

The *Nuclear Membrane* is a delicate membrane surrounding the nucleus. *With LM* it appears as a single blue line. *With EM* the nuclear membrane consists of two layers, which are separated by a *Perinuclear space*. It possesses nuclear pores guarded by thin septa.

The nuclear membrane plays an active part in the interaction between the nucleus and the cytoplasm.

2. Nuclear Sap

The *Nuclear Sap* is the semifluid colloidal material of the nucleus and is very faintly stained.

3. Nucleoli

The *Nucleoli* (1 to 5) are little round deep blue staining bodies within the nucleus. They are rich in RNA. *With EM* the nucleoli show a granular structure having a dark material *nucleolonema* and a light material *pars amorpha*.

Nucleoli are important stations for nucleic acid synthesis.

4. Chromatin

Chromatin are little blue staining particles within the nucleus rich in DNA. In reality they are stainable parts of chromosomes.

With EM : Chromatin appears as dark granular material.

Chemically : Chromatin is DNA combined with various proteins mainly histones.

States : Chromatin occurs in two interchangeable states of *extension* and *condensation*.

(a) *Extended chromatin* (*Euchromatin*) are uncoiled segments of chromosomes and stain poorly or not at all. They are active and direct the cell activities in the production of protein.

(b) *Condensed chromatin* (*Heterochromatin*) are coiled segments of chromosomes and stain deep blue. They form the chromatin particles of interphase nucleus, and are inert and inactive.

In the interphase nucleus, the chromosomes do not break up into chromatin particles (as previously understood) but the completely coiled threads become uncoiled at certain sites along their course. Thus the thread like chromosomes remain intact, but have extended (uncoiled) and condensed (coiled) segments along their lengths. And only the coiled segments are dense enough to be stained as chromatin particles.

With the onset of prophase, the extended chromatin also become coiled in their entire length and the whole structure looks little rod like bodies ; these are chromosomes and are present in constant number in the cells of each species.

Sex Chromatin (*Barr's Body*)

In females, 85% of cells show a densely staining planoconvex mass on the inner surface of the nuclear membrane. This is Sex chromatin which represents an inactive 'x' chromosome. In about 3% of neutrophils a small globular mass of sex chromatin, often termed *drum stick,* (See Fig. 18B) is attached to one of the nuclear lobes by a thin stalk. In males sex chromatin is absent, because the only 'x' chromosome is active (extended form).

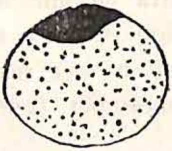


Fig. 3. Nucleus showing sex-chromatin

Chromosomes

Chromosomes are little rod-like or thread-like bodies in the nucleus which take a deep basic stain. They make their appearance with the onset of prophase. Chemically chromosomes are DNA, and contain hereditary material.

1. *Number* : Mature sex cells, ova and sperms, have 23 chromosomes (*haploid number*). Out of 23, one is *sex chromosome* and the remaining 22 are *autosomes.* The sex chromosome in ovum is always 'x', while in sperm it is either 'x' or 'y'.

At fertilization the *diploid number* (23 pairs) is restored. The fertilized ovum, and all somatic cells contain 46 chromosomes each. Out of these, 22 pairs are autosomes and one pair consists of sex chromosomes. In male somatic cells the sex chromosome pair consists of 'x' and 'y' ; in female somatic cells the sex chromosome pair consists of 'x' and 'x' (i.e., 2 'x').

2. *Chromosome Nomenclature* : The chromosome pattern of an individual is known as *Karyotype.* Human chromosomes have been classified into 7 groups A to G, and each has been given a number mainly on the length of chromosomes and the position of

the centromere : Group A, 1 to 3; B, 4 and 5; C, 6 to 12 and 'X'; D, 13 to 15; E, 16 to 18; F, 19 and 20; G, 21, 22, and 'Y'.

3. *Function* : Chromosomes control the heredity and activities of the cell because of genes, which are distributed in a linear fashion along it. *Genes are units of inheritance.* and in extended chromatin direct the activities of the cell in the production of proteins. Chemically genes are segments of DNA molecule containing a particular nucleotide sequence.

4. *Chromosomal Abnormalities* : Sometimes the number of chromosomes may be less, or more. This is due to non-disjunction, i.e., non-separation of a chromosome pair during reduction division, so that one daughter cell (gamete) receives an extra chromosome (24) and the other receives one less (22). The union of these abnormal gametes (ova or sperms) with normal sperms or ova result in abnormal offspring with altered number of chromosomes (either sex chromosome or autosome).

Some Important Examples : A. Sex chromosome abnormalities:—

1. Klinefelter's Syndrome (xxy): The cells contain 47 chromosomes—an extra 'x' sex chromosome. These are males, but are sterile and have underdeveloped testis

2. Turner's Syndrome (xo) : The cells contain 45 chromosomes—an 'x' chromosome is absent. These are females having underdeveloped ovaries, short stature and webbed neck.

B. Autosome abnormality :—

Mongolism (Down's Syndrome—Trisomy 21) : The cells contain 47 chromosomes, the extra chromosome resemble pair number 21. These have mental retardation and congenital heart defects.

CELL DIVISION

I. Amitosis

The nucleus divides unequally into two, followed by the division of the cell. It is rare in human beings.

II. Mitosis

Mitosis is characterised by a series of changes in which there is equal division of nuclear material (Karyokinesis), followed by the division of the cell (cytokinesis).

Phases of Mitosis : Prophase, Metaphase, Anaphase, Telophase

Prophase :

The nuclear membrane and the nucleolus disappear. The chromatin granules resolve into chromosomes. As a prelude to mitosis each chromosome is duplicated, each of which is called a *chromatid*. The paired chromatids lie side by side and are united at one point only termed the ***centromere.*** The centriole(s) divides, move in the opposite direction and finally take up positions at opposite poles of the cell. The centrioles are connected by microtubules forming acromatic spindle.

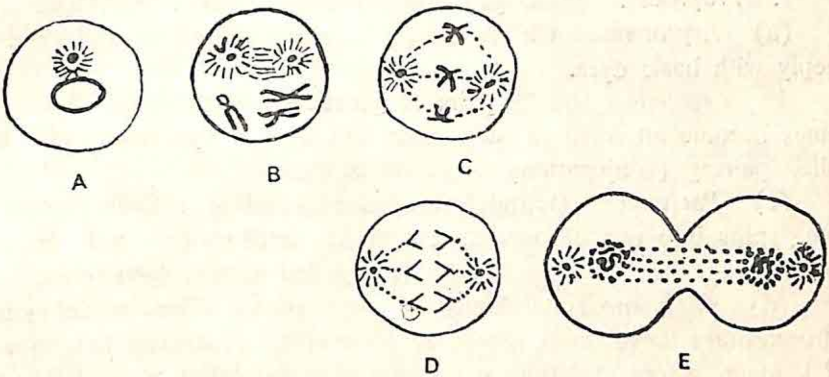


Fig. 4. Stages of Mitosis: A. Resting Cell, B. Prophase, C. Metaphase, D. Anaphase,, E. Telophase.

Metaphase (*Aster phase*)

The 'V' or 'J' shaped chromosomes arrange themselves at the equator (metaphase plate).

Anaphase

The centromere divides and the two chromatids become completely separated from each other. The spindle tubules pull the separated group of chromatids to opposite poles. The two groups of chromatids, now chromosomes are identical.

Telophase

Constriction develops at the equator of the elongated cell. It deepens and divides the cell into two daughter cells. Meanwhile, in each daughter cell, the chromosomes lose their identity, become uncoiled to varying extent and are seen as chromatin particles. The nucleoli and the nuclear membrane have reformed.

III. Meiosis (*Reduction division*)

Meiosis occurs only in sex cells during maturation, and comprises *1st* and *2nd* meiotic divisions.

First Meiotic division

1. *Prophase* : Prolonged and is divided into 4 sub-stages:

(a) *Leptotene* : Chromosomes become prominent and stain deeply with basic dyes.

(b) *Zygotene* : The 23 **pairs** of genetically homologous chromosomes become attracted to each other and lie side by side. This is called pairing (conjugation) of chromosomes.

(c) *Pachytene* (tetrad formation and coiling) : Each chromosome splits into two chromatids except at centromere, and forms *tetrads*; the chromatids become partially coiled around each other.

(d) *Diplotene* (interchange of segments) : The homologous chromosomes move apart except at *chiasmata.* Chiasmata are points of contact, where exchange of genetic material takes place between two chromatids. At the chiasmata parts of two chromatids (one from each homologous pair) **break and then join** diagonally. This is called crossover, which results in redistribution of genetic material. Finally the chromosomes (with two chromatids) uncoil and slip apart (*Diakinesis*).

2. *Metaphase* : The chromosomes with paired chromatids arrange themselves at the equator.

3. *Anaphase* : ***Centromeres do not divide*** **and each member** of homologous chromosomes, consisting of a pair of chromatids is dragged to opposite poles of the spindle.

4. *Telophase* : Cell divides into two containing one half (haploid) chromosomes.

Second Meiotic division

Follows closely after the *1st* meiotic division with practically no resting stage. This is exactly like mitosis but the phases are much shortened. Four cells are derived from the two cells of 1st meiotic division. Each has haploid number of chromosomes and each has its own particular share of the genetic material.

Differences between Mitosis and Meiosis :

Mitosis is an equating division as regards the number of chromosomes and the distribution of genetic material.

Meiosis : The 1st meiotic division results in (1) reduction of chromosome number to half and (2) segregation (redistribution) of genetic material.

The 2nd meiotic division results is further redistribution of genetic material, but the number of chromosomes remains haploid.

Basic (Primary) Tissues and Organs

All cells originate from existing cells by a process of cell division. Multicellular organisms including man begin existence as a single cell, which divide and redivide. Differentiation gives rise to specialized groups of cells, each group differing in structure and function. These specialized groups of similar cells are called *tissues*. There are 4 basic tissues : ***epithelial***, *connective*, *muscular* and *nervous*. An *organ* is a combination of different tissues in varying proportions, mostly consisting of epithelium, connective tissue and muscle with a supply of vessels and nerves. Some however, may lack epithelium or muscle, or both.

3 Epithelial Tissue and Glands

EPITHELIAL TISSUE (EPITHELIUM) is collection of cells arranged in the form of sheet which cover the external surface of the body and line the internal surfaces of hollow viscera and closed serous cavities. They also form glands.

Features of Epithelium in General

1. Cells are closely packed together.
2. Intercellular substance is reduced to a minimum.

Classification :

Based on the number of cell layers.

A. Simple epithelium-cells arranged in one layer. All cells rest on the basal lamina.

B. Stratified epithelium-cells arranged in two or more layers ; only the deepest cells rest on the basal lamina.

A. Simple epithelium further classified according to the shape and size of cells.

I Simple Squamous Epithelium

Features :

1. Cells in one layer.
2. Cells are flattened i.e , each cell has length and breadth but negligible thickness.
3. Nucleus : Flattened and circular.
4. In *Surface view* individual cells have irregular hexagonal outline and the whole sheet gives a mosaic appearance.
5. In *vertical section* the cells look like thin plates and the flattened nucleus produces a bulge in the centre of the cell.

Chief Distribution :

Alveoli of lung, parietal layer of Bowman's capsule, descending limb of Henle's loop, lining of blood and lymph vessels and serous cavities.

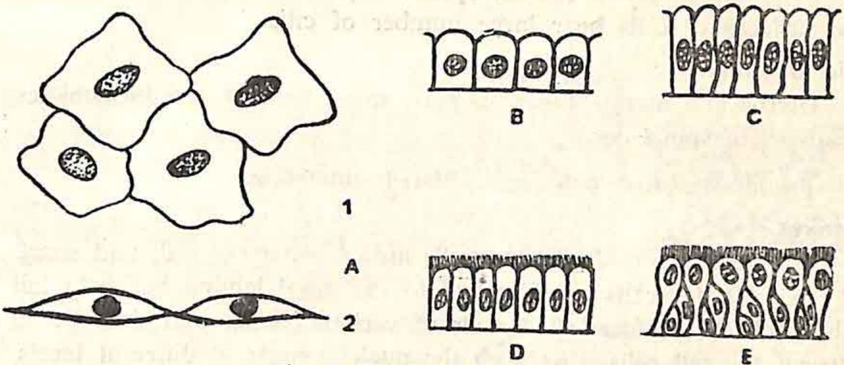


Fig. 5. Simple Epithelium:
A. Simple, **Squamous, 1. Surface view,** 2. Vertical section, B. Simple cuboidal, C. Simple columnar, **D. Simple columnar ciliated.** E. Pseudostratified columnar ciliated.

II Simple cuboidal epithelium

Features :

1. Cells in one layer.
2. Cells are nearly cubical i.e., length, breadth and thickness are equal.
3. Nucleus : Spherical and central in position.
4. In *vertical section* : The epithelium appears as a row of squares.

Chief distribution :

Follicles of thyroid gland, proximal and distal convoluted tubules, ascending limb of Henle's loop and all collecting tubules, respiratory bronchiole, pigment layer of retina, germinal epithelium of ovary, ducts of many glands.

III Simple columnar epithelium

Features :

1. Cells in one layer.
2. Cells are columnar i.e., taller than broad.
3. Nucleus : Oval, situated near the base or in the centre of the cell.
4. *In vertical section* : the epithelium appears as a pile of bricks.

Chief distribution :

Gall bladder, stomach, small intestine, most of large intestine.

In simple columnar ciliated epithelium, besides above features the free surfaces of cells bear large number of cilia.

Chief distribution :

Uterus and uterine tubes in part, small bronchi and bronchioles ependyma of spinal cord.

IV Pseudo-stratified columnar ciliated epithelium

Features :

1. Cells in one layer, but cells are of two types, tall and short.
2. All the cells are attached to the basal lamina but only tall cells reach the surface, short cells of various shapes and sizes lie in between the tall cells. As such the nuclei appear at different levels.
3. Free surface of tall cells bear cilia.

Chief distribution :

Trachea and bronchi ; vas deferens and epididymis bear non-motile cilia.

B. Stratified Epithelium : Further classified on the shape of the surface cells.

I Stratified Squamous Epithelium

Features :

1. Cells in many layers.
2. Basal cells near basal lamina are columnar, intermediate cells cuboidal or polyhedral, and surface cells flattened. Nuclei crowded towards basal region.

TYPES : Non keratinised, keratinised.

(a) *Non-keratinised*—all cells are living and have nuclei.

Chief distribution :

Lining of mouth cavity, tongue, tonsil, pharynx, oesophagus, epiglottis, cornea, vagina.

(b) *Keratinised* : The superficial cells have lost their nuclei and are dead scales. They are converted into a horny material called keratin (sclero-protein) which takes acidophilic staining.

Chief distribution :

Epidermis of Skin.

II Transitional epithelium

It is a plastic type of epithelium ; its appearance varies with with relaxation and distension of the organ.

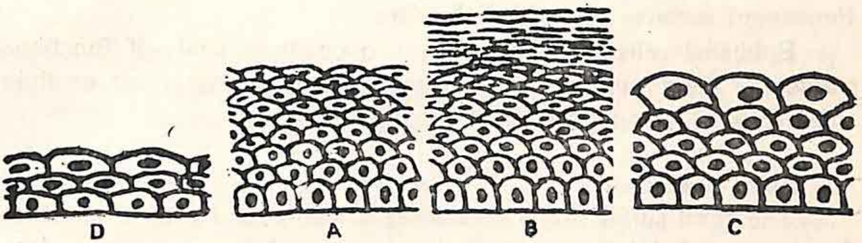


Fig. 6. Stratified Epithelium : A. Stratified squamous non-keratinised, B. Stratified squamous keratinised, C. Transitional-relaxed, D. Transitional-stretched

Features :

1. Cells arranged in many layers, usually 3 to 5 layers, all cells are living.
2. Most of the cells are polyhedral. Nuclei uniformly distributed.
3. In relaxed condition of the organ, the surface cells are large, umbrella or balloon shaped ; in distended condition, the surface cells become flattened.

Chief distribution :

Clayx minor and major, pelvis of ureter. ureter, urinary bladder, proximal parts of urethra.

III Stratified columnar epithelium

Features :

Cells in many layers : Superficial cells are columnar in shape.

Chief distribution :

Confined in patches in —fornix of conjunctiva, anal mucous membrane, cavernous part of male urethra.

IV Stratified cuboidal epithelium

Features :

Cells in many layers : All cells are cuboidal.

Chief distribution :

Ducts of sweat gland and mammary gland, seminiferous tubules of testis, developing ovarian follicles.

Functional surfaces of epithelial cells :

Epithelial cells may have one, two or three kinds of functional surfaces. *Basal surface*, *free surface* exposed to either air or fluid, *side surfaces* in contact with other cells.

Basal Surface

The basal surface rests on the basal lamina and receive nutriment from the underlying vascularised connective tissue. In some locations the basal surface show *infoldings* of the plasma membrane. Besides providing additional anchorage it increases basal surface area for active transport of fluid and ions.

Basal Lamina

With EM *the basal lamina consists of a thin amorphous layer of mucoprotein,* and is produced by the epithelial cells. Outside the basal lamina but associated with it is a mesh of delicate reticular fibres derived from connective tissue fibroblasts.

The combination of basal lamina and the layer of reticular fibres appears as a single membrane, termed the *basement membrane*, under the optical microscope.

Free Surface (Various specializations)

1. Microvilli

Microvilli are ultra-microscopic finger like projections from the free surface of some columnar cells and consist of a core of apical cytoplasm covered by plasma membrane.

Example : *Striated borders* of intestinal epithelial cells, *brush borders* of proximal convoluted tubules of kidney, both of which are closely packed collections of microvilli.

Function : Increase the surface area and are concerned with selective absorption.

2. Stereocilia

Non-motile cilia are called *Stereocilia.* They are actually long flexous microvilli, e.g., in epididymis and vas deferens ; they help in secretion.

3. Cilia

Cilia are thin hair like processes.

EM : Cilia in T.S. show 9 pairs of longitudinal fibrils arranged in a ring with a single pair in the centre. At the base of each cilium there is a dense granule called *basal corpuscle* to which the cilium is anchored. The structure of basal corpuscle (i.e., the intracellular part of cilium) is similar to that of a centriole consisting of 9 circumferential triplets around a central pair.

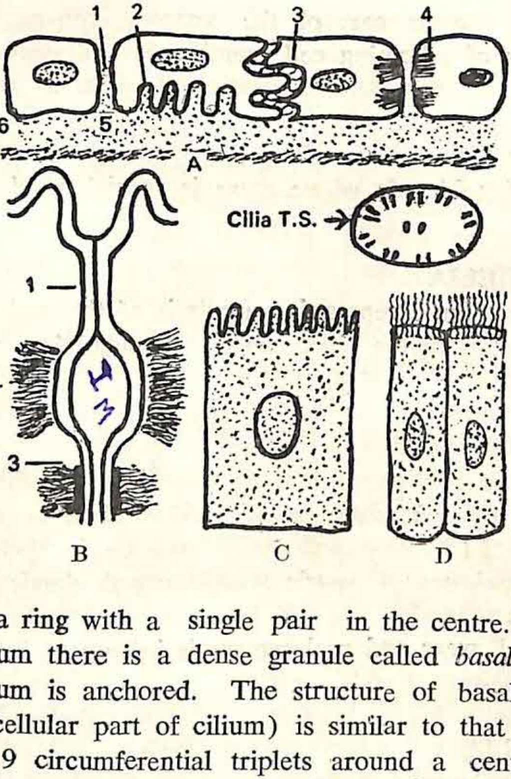


Fig. 7. Modifications of cell surfaces : A1. intercellular substance, A2. Infoldings of basal plasma membrane, A3. Interlocking projections, A4. Desmosome, A5. Basal lamina, A6. Reticular fibres, A5+A6 =Basement membrane, B. Junctional complex —1. Tight junction, 2. Loose junction, 3. Desmosome, C. A cell showing microvilli, D. Two columnar cells showing cilia. (IM)

Distribution : In respiratory tract, uterine tube, uterus, efferent ductules of testis.

Function : Cilia beat towards the outlet of the body and help in the movement of mucus, ova or sperm.

Side Surfaces (Specialization for cell to cell attachment) :

1. Interlocking Projections are a series of ridges and grooves on the side surfaces of adjacent cells, and are fixed by an adhesive cementing material, the *intercellular substance.*

2. Junctional Complex in Simple Columnar Epithelium : EM shows it to consist of 3 parts :

(*a*) *Tight junction* extends around the entire apical circumference of the cell. There is fusion of outer leaflet of opposing cell membrane.

(*b*) *Loose junction*, the middle part of the complex, is a region of close apposition of cell membrane completely surrounding the cell.

(*c*) *Desmosome*, the deepest part of the complex, consists of thickening of inner layers of adjoining cell membranes and condensation of cytoplasm on them. Bundles of filaments (tonofibrils) converge at these sites.

Apart from junctional complex, *desmosome* are particularly present in deep layers of epidermis where there is special need for cellular cohesion.

NUTRITION OF EPITHELIA

All epithelia are avascular except stria vascularis of the cochlea. They derive their nutrition from the blood vessels of underlying connective tissue.

REGENERATION OF EPITHELIA

In epidermis there is continuous loss of superficial keratinised cells which are replaced by continuous mitosis taking place in stratum germinativum. In G.I.T. new cells arise by mitotic division of epithelial cells at the bases of gastric and intestinal glands and replace the surface cells.

On the other hand, wear and replacement is infrequent in respiratory passages and in most glands.

SOURCE OF EPITHELIA

From all three germ layers :—

From ectoderm : epidermis of skin and corneal epithelium.
From entoderm : lining of alimentary canal.
From mesoderm : lining of urinary and reproductive tracts.

MESOTHELIUM, ENDOTHELIUM

Conventionally the lining of serous cavities (peritoneal, pleural and pericardial) are called *mesothelium*, and the lining of blood and lymph vessels *endothelium*, although histologically they are epithelia in all respects.

Synovial Membrane and sheaths are lined by a discontinuous layer of fibroblasts. They are not epithelium but exposed connective tissue surfaces.

Mucous Membranes (*Mucosa*) are moist sheets lining all internal hollow organs that open to the exterior e.g., respiratory, alimentary, urinary and genital tracts. It consists of (a) lining epithelium and (b) subepithelial connective tissue (lamina propria). Only in G.I.T. it consists of a third element, the muscularis mucosae which separates mucosa from submucosa.

GLANDS

Glands are specialized cells which produce secretion. Secretion is the elaboration and release by the cells of a fluid containing hormones or enzymes. Most glands arise as ingrowth from the epithelium into the connective tissue. In exocrine glands the deepest cells become secretory, the connecting cells persists to form duct; in endocrine glands the connecting cells disappear, and the deepest cells remain to secrete directly into blood and lymph.

Mechanism of Secretion: Gland cells are in a state of continual activity. In the formation of secretion the following events take place: 1. Mitochondria provide the energy source; 2. Ribosomes studded on the outer surface of granular endoplasmic reticulum are sites of protein synthesis for secretion; 3. Synthesized proteins move up to Golgi complex where they are stored and condensed; 4. Finally enclosed in Golgi membrane they are released from the luminal surface of the cell.

Classification of Glands

A. According to the method of secretion transport:

1. *Exocrine glands*: discharge their secretion either directly or by means of a duct on the epithelial surface from which the gland arose.

2. *Endocrine glands*: release their secretion directly into blood or lymph vessels. These glands have no ducts and are also called *ductless glands*.

B. According to gland cell participation during secretion:

1. *Merocrine*: The cell remains intact, there is no cytoplasmic loss, only the secretory material is discharged.

Ex: Most glands, ordinary sweat glands (also termed eccrine sweat glands).

2. *Apocrine*: The luminal part of the cell disintegrates. There is some loss of apical part of the cytoplasm.

Ex. Mammary glands, specialized sweat glands termed apocrine sweat glands.

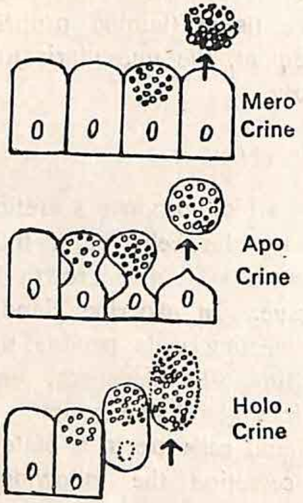


Fig. 8. Methods of cell secretion.

3. *Holocrine* : The entire cell disintegrates and is discharged as secretion.

Ex. Sebaceous gland.

Classification of Exocrine Glands

A. Based on the number of cells :

1. *Unicellular glands* (Goblet cells): *Goblet cells* are unicellular mucous glands. They are inverted flask shaped cells. The nucleus is situated in the narrow basal part, the luminal part contains granules of mucigen which usually gives an empty looking appearance. When the mucigen granules are preserved they stain fairly well.

Distribution : Scattered in the epithelium of trachea, bronchi, intestine.

2. *Multicellular glands* : Further classified according to 1. Situation of the gland, 2. Arrangement of duct system and 3. Shape of the secreting part. The simplest gland lacks a duct. The *simple glands have single unbranched duct, compound glands have branched ducts.* The secretory end pieces may be *tubular* (tube like), *alveolar* (rounded and spherical), or *tubulo alveolar* (a combination of tubules and alveoli).

(a) *Intra epithelial glands* : Simplest multicellular glands consisting of a number of secreting cells that lie wholly within the thickness of the epithelium. Ex. In the epithelium of urethra.

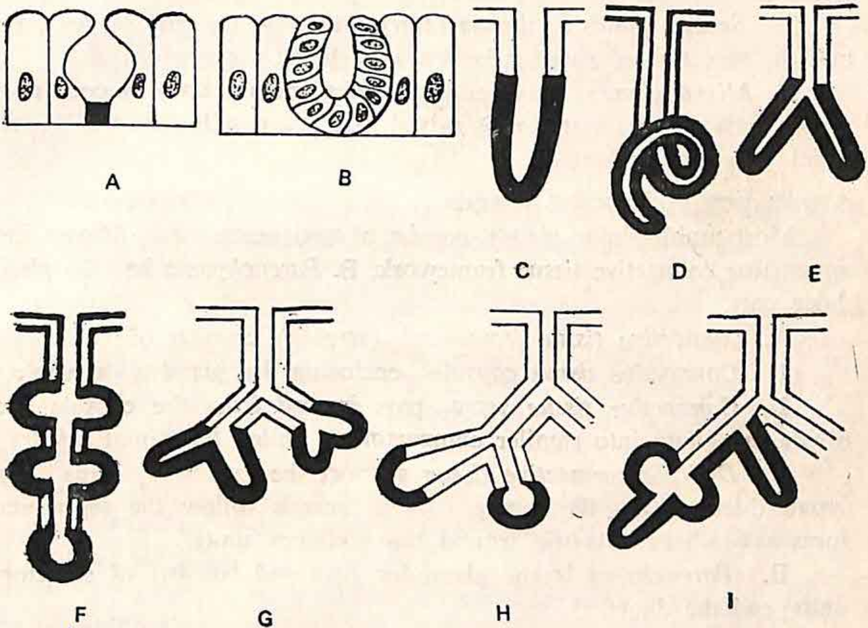


Fig. 9. Glands: A. Goblet cell, B. Intra-epithelial gland, C. Simple tubular, D. Simple coiled tubular, E. Simple branched tubular, F. Simple, branched alveolar, G. Compound tubular. H. Compound alveolar, I. Compound tubulo-alveolar: Secretory portion black. ducts double contoured.

(b) *Simple glands* :

(i) Simple tubular glands, Ex. Intestinal glands.
(ii) Simple coiled tubular glands, Ex. sweat glands.
(iii) Simple branched tubular glands, Ex. gastric glands.
(iv) Simple branched alveolar glands, Ex. Sebaceous glands.

(c) *Compound glands* :

(i) Compound tubular glands, Ex. glands of Brunner.
(ii) Compound alveolar glands, Ex. some glands of respiratory tract.
(iii) Compound tubulo-alveloar glands, Ex. Salivary glands, pancreas, lacrimal glands, mammary glands.

B. According to the types of secreting cells and the nature of secretion.

1. *Mucous glands* : contain mucous secreting cells and the secretion is slimy, Ex. Lingual glands, palatine glands.

2. *Serous glands* : the secretory units contain only serous cells and the secretion is watery, Ex. Parotid gland, pancreas.

3. *Mixed glands* : the secretory units contain both mucous and serous cells and the secretion is mixed, Ex. Submandibular, sublingual, labial and buccal glands.

Architecture of Exocrine Glands

Most multicellular glands consist of two parts, A. *Stroma* i.e. supporting connective tissue framework, B. *Parenchyama* i.e., the glandular part.

A. *Connective tissue framework* (*stroma*) consists of :

1. *Connective tissue capsule*—enclosing the gland as a whole.

2. *Connective tissue septa*—pass inward from the capsule and divide the gland into smaller compartments called *lobes* and *lobules.*

3. *Delicate connective tissue* support the secretory units and small ducts within the lobule. Blood vessels follow the septa and form a capillary network around the secretory units.

B. *Parenchyma* is the glandular part and consists of secretory units and the ducts.

Classification of Endocrine Glands

The endocrine tissue occurs in three forms :

(a) *Discrete glands* having only endocrine functions.

(1) Hypophysis cerebri, (2) Thyroid gland, (3) Parathyroid glands, (4) Adrenal (suprarenal) glands.

(b) *Forming a part of the gland ;* these glands have also other functions besides endocrine functions. They are testis, ovary, pancreas, thymus, placenta.

(c) As isolated endocrine cells in the lining cells of gastro-intestinal tract—also termed paracrine glands.

Architecture of Endocrine Glands :

Like the exocrine glands, the endocrine glands have two parts :

A. *Stroma* (connective tissue framework) consisting of :—

1. *Connective tissue capsule* enclosing the gland.

2. *Delicate septa.*

3. Fine framework formed by *reticular fibres.*

B. *Parenchyma* consisting of secreting cells only which are arranged in cords or plates around the sinusoids or large capillaries. Exception—Follicular arrangement in thyroid gland.

4 Connective Tissues

The connective tissues unite or support other tissues and act as universal padding material. It is mesodermal in origin and develops from mesenchyme.

Features

1. Cells are widely scattered.
2. Intercellular substance is increased to a maximum.

Classification

Based on the nature of intercellular substance.

I. Connective tissue proper : Intercellular substance varies from soft jelly to semisolid in consistency.

II. Cartilage : Intercellular substance is solid but has a rubbery consistency.

III. Bone : Intercellular substance is solid and contains calcium salts.

IV. Blood & Lymph : Intercellular substance is fluid.

I CONNECTIVE TISSUE PROPER

Component parts :

A. Intercelluar substance (Matrix or round substance).
B. Fibres.
C. Cells.

A. Ground substance

The ground substance is amorphous and varies from soft jelly to semisolid in consistency. In *fresh state* it is homogeneous and transparent. *Chemically* it is protein polysaccharide. The ground substance plays a role in nutrition of cells and exchange of metabolites.

B. Fibres

Three types : Collagen, Elastic and Reticular.

Collagen Fibres

Features

1. Collagen fibres run in straight or wavy bundles.
2. Individual fibres do not branch but a group of fibres may pass from one bundle to another.
3. Each fibre is a collection of variable number of *collagen fibrils* which are fine threads (.3 to .5 μ thick).
4. EM : The fibrils have transverse (cross) striations at regular intervals of 640Å. Each fibril consists of a number of *microfibrils*.

Each molecule of collagen is called *tropocollagen* which consists of three polypeptide chains that intertwine into a triple helical molecule.

Chief distribution

Tendon, aponeurosis, intervertebral disc.

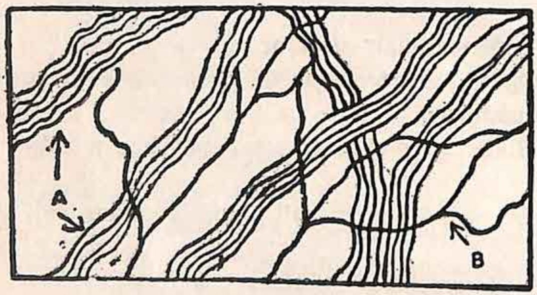


Fig. 10. a. Collagen fibres, b. Elastic fibres

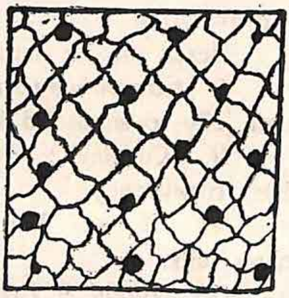


Fig. 11. Reticular fibres

Elastic Fibres

Features

1. Elastic fibres run singly.
2. They branch and anastomose to form a network.
3. Since the fibres are elastic, the cut ends curl up.

Elastic fibres stretch easily but return to their original length when released after stretching. *Elastic fibres stain selectively by orcein.*

Chief distribution

Ligamentum nuchae, ligamentum flava, internal elastic lamina of arteries.

Recticular Fibres

Features

Reticular fibres are fine *silver staining fibres,* which branch profusely and anastomose to form a dense network. They are supposed to be immature collagen fibres because reticular fibres also possess transverse striations at regular intervals of 640 Å.

Chief distribution : In close association with basal lamina ; in lymph nodes, liver, spleen, bone marrow and endocrine glands.

C. Cells of Connective tissue

1. Fibroblasts

Features :

Shape—Fusiform or spindle shaped with processes.

Cytoplasm—Scanty and clear.

Nucleus—Large, oval and centrally placed.

Functions :

1. Formation of collagen fibres, and probably elastic and reticular fibres.
2. Manufacture of mucoproteins of the ground substance.
3. Important role in repair process and formation of scar tissue.

2. Mast Cells

Features :

Shape—Round or oval with varying sizes.

Cytoplasm—Packed with large basic granules. These granules stain *metachromatically* with **basic aniline dyes, i.e.,** the resulting colour of the granules is different from the dye used. Thus with a blue dye toluidine blue the granules take a purple colouration.

Nucleus—Small, central and often hidden by the granules.

Function :

Mast cells produce heparin, histamine, hyaluronic acid and 5-hydroxy tryptamine (serotonin).

3. Macrophages (Histiocytes, Resting wandering cells, Phagocytes).

Macrophages form the main component of reticulo-endothelial system.

Features :

Shape—Large irregular cells.

Cytoplasm—Contains coarse granules and vacuoles.

Nucleus—Small and oval.

Function :

These cells are usually fixed but are capable of amoeboid movement. They ingest foreign particulate matters including bacteria, and thus are important in general and local defence mechanisms. They also take part in the destruction of worn out R.B.C. and debris of dead cells.

4. Plasma cells

Features :

Shape—Small cells, round or oval.

Cytoplasm—Homogeneous and lightly basic.

Nucleus—Small, eccentric, and surrounded by a halo; chromatin within the nucleus arranged like a cart wheel.

Function :

Formation of antibodies (immunoglobulins).

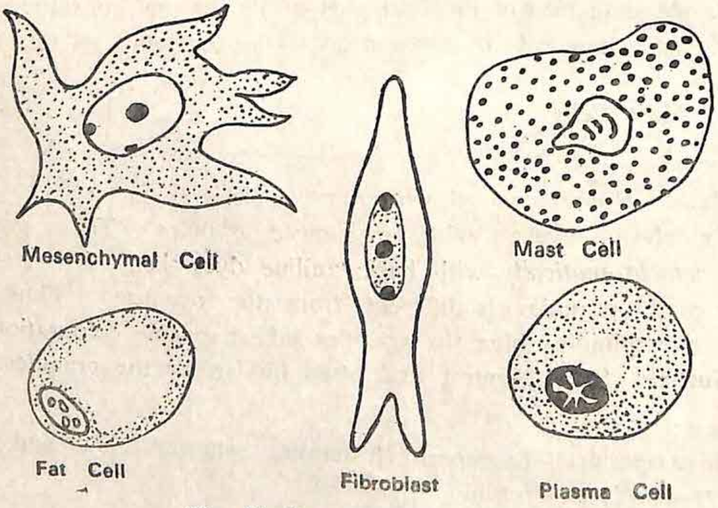


Fig. 12. Connective tissue cells

5. Fat cells

Features :

Shape—Round when single, polyhedral when in groups.

Cytoplasm—Forms a thin peripheral layer around the central fatty material.

Nucleus—Peripheral.

In ordinary histological preparation the fat is usually dissolved out and the cells look vacant giving a signet ring appearance. Sudan IV stains frozen section of fatty tissues red.

Function :

Store house of food material (as fat).

6. Pigment cells

Pigment cells are filled with melanin granules. *Melanocytes* synthesize pigments, while *melanophores* carry it. Pigment cells occur in the skin, iris, pigment layer of retina.

7. Reticular cells

Reticular cells are stellate shaped cells with processes and are found in reticular connective tissue specially at the intersection of fibres.

Types

(a) *Primitive reticular cells* resemble embryonic mesenchyme and can differentiate into diverse cell types.

(b) *Phagocytic reticular cells* (fixed macrophages). They may become free in inflammatory conditions.

8. Undifferentiated mesenchymal cells

These are original embryonic mesenchymal cells resembling small fibroblasts but the cytoplasm is somewhat granular. They usually lie along the wall of blood vessels. They can give rise to all cells of connective tissue.

Connective Tissue Proper Classified :

A. Areolar tissue

In fresh condition it is soft and transparent, and like a collapsed sponge it contains numerous little chambers occupied by little amount of amorphous ground substance. These little chambers led to the term areolar tissue (Areola means a small area). It has wide distribution.

B. Dense connective tissue

It contains mainly fibres with some cells and little ground substance.

1. *Elastic tissue* : Elastic fibres predominate.
2. *White fibrous tissue* : Collagen fibres predominate.
   - (a) *Irregular* : Collagen bundles arranged in an intertwining network.
   - (b) *Regular* : Collagen bundles arranged in parallel sequence.

C. Specialized connective tissue ;

1. *Reticular tissue* : It comprises reticular fibres and cells.

2. *Mucous connective tissue* : It is a form of loose connective tissue. Cells are stellate fibroblats, matrix is soft jelly rich in hyaluronic acid. Ex. Wharton's jelly of umbilical cord. Vitreous body of the eye.

3. *Adipose tissue* : It consists of aggregation of fat cells.

Types

(a) *White adipose tissue* has large cells each containing a single large fat droplet (Unilocular).

(b) *Brown adipose tissue* has smaller cells, each containing numerous fat droplets (Multilocular).

D. Serous Membrane

Serous membrane consists of a thin layer of connective tissue covered by a layer of *mesothelium*. They line closed body cavities; Ex. peritoneum, pleura, serous pericardium.

E. Macrophage system (Reticulo-Endothelial system)

This is a wide spread system of highly phagocytic cells, concerned with ingestion and removal of foreign particulate matters (see Macrophages).

Chief distribution :

Macrophages of connective tissue, primitive reticular cells of lymphoid tissue and spleen, cells lining the sinusoids of liver (Kupffer's cells), bone marrow (Littoral cells) and endocrine glands, Monocytes of blood. Pericytes of capillaries, dust cells of lung, Microglia of CNS is sometimes included in this group.

II CARTILAGE

Cartilage is a specialized type of connective tissue contalnlng encapsulated cartilage cells. It forms the skeletion of the body in early life most of which is replaced by bone in adult; but persists as articular cartilage, costal cartilage, laryngeal, tracheal and bronchial cartilages, and in nose and ears. It is avascular and is devoid of lymphatics, and nerves.

A. Component Parts :

1. Cells (chondrocytes), 2. Ground substance, 3. Fibres—collagen, elastic.

1. Cells (Chondrocytes)

Chondrocytes are large cells (upto 40μ) having a large nucleus. The cells lie in little spaces called *lacunae* and are surrounded by a *capsule which takes a deep basic stain.* The cartilage capsule is a zone of most recently formed matrix, which has a high concentration of acid mucopolysaccharide. When young cells occur singly. Later on the cells divide and they usually occur in groups of 2, 4 or 8 forming the so-called *cell nests.*

Function : Produces ground substance as well as fibres.

2. Ground Substance :

The ground substance is solid but of rubbery consistency. *Chemically* it consists of chondro-mucoprotein.

B. Classification

1. Hyaline cartilage, 2. **Elastic cartilage.** 3. Fibro cartilage.

1. Hyaline Cartilage

Features :

(i) Presence of encapsulated cartilage cells in abundance.

(ii) Ground substance homogeneous (glass like) and lightly basophilic. It contains a dense network of very fine collagen fibres, but the refractive index of the fibres and ground substance is the same, so the fibres are not seen (masked) under optical microscope. However, the fibres can be seen under polarising microscope.

(iii) Perichondrium—Except on articular surfaces, the hyaline cartilage is covered by a vascular fibrous membrane termed *perichondrium* whose inner part is more cellular.

Chief distribution :

Trachea, bronchi, thyroid and cricoid cartilages, costal cartilage, most articular cartilages and epiphyseal cartilage.

2. Elastic Cartilage

Features :

(i) Presence of encapsulated cartilage cells, singly or in groups.

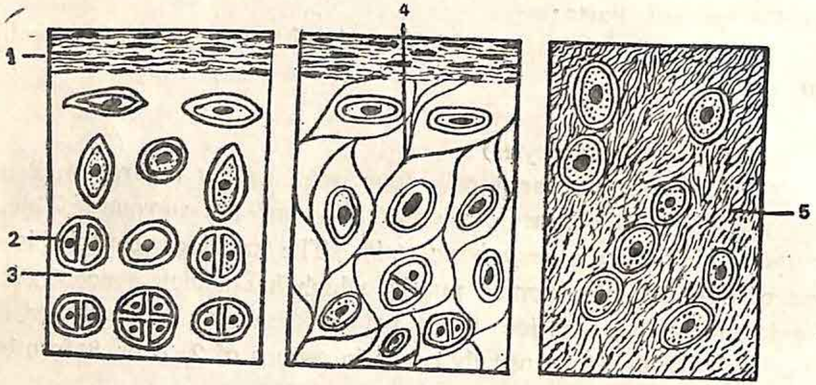


Fig. 13 Fig. 14 Fig. 15

Fig. 13 Hyaline cartilage, Fig 14 Elastic cartilage, Fig. 15 Fibro cartilage. 1. Perichondrium, 2. Cartilage cells in capsule, 3. Hyaline matrix, 4. Elastic fibres, 5. Collagen fibres.

(ii) Ground substance contains network of branching and anastomosing elastic fibres.

(iii) Perichondrium similar to hyaline cartilage.

Chief distribution :

Epiglottis, corniculate, cuneiform and apices of arytenoid cartilages, auricle, external auditory meatus.

3. Fibrocartilage

Features :

(i) Presence of encapsulated cartilage cells, few in number; usually single or in rows.

(ii) Ground substance contains thick bundles of collagen fibres.

(iii) Perichondrium absent, the peripheral part of the fibrocartilage merges with the adjacent connective tissue.

Chief distribution :

Intervertebral disc, pubic symphysis, glenoidal and acetabular labra.

Growth of Cartilage

Cartilage grows by 2 methods: (a) *Interstitial growth*—when cartilage grows from within (central part); (b) *Appositional growth*—when cartilage grows by adding new layers on its surface by the cells of perichondrium.

Nutrition of Cartilage

Cartilage is avascular. Hyaline and elastic cartilages get nutrition from the blood vessels of the perichondrium; fibrocartilage from blood vessels of surrounding connective tissue, and articular cartilage from synovial fluid.

In old age due to poor nutrition, calcification occurs in scattered areas of hyaline cartilage with subsequent bone formation in small areas e.g., thyroid cartilage.

III BONE

Bone is a specialized type of connective tissue in which the intercellular substance is solid and contains calcium salts.

Types: Compact bone and spongy (cancellous) bone.

The *compact bone* is dense like an ivory and always placed on the outer part of a bone. The *spongy bone* is a network of trabeculae with intercommunicating spaces and is placed in the interior of a bone, and increases considerably near the ends of long bones.

Medullary Cavity: In the interior of long bones there is a medullary cavity filled with bone marrow and lined by a vascular membrane called endosteum.

The short bones consists of spongy bone covered with a thin layer of compact bone. The cranial bones consists of two plates (tables) of compact bone separated by spongy bone filled with blood vessels called diploe.

Component parts: A. Ground substance, B. Fibres, C. Bone cells.

A. Ground substance comprises

(a) Organic material—Chiefly protein polysaccharide complex.

(b) Inorganic material—Calcium hydroxy apatite crystals.

B. Fibres

Fine collagen fibres in bundles of 3 to 5μ in diameter.

C. Bone cells:

1. Osteoblasts, 2. Osteocytes, 3. Osteoclasts.

1. **Osteoblasts** are active bone cells and secrete bone matrix. They are oval cells with delicate processes having large nucleus.. The cytoplasm is basophilic because of large number of rough surfaced endoplasmic reticulum. They are also rich in alkaline phosphatase.

2. **Osteocytes** are restng bone cells and lie within lacunae. They are lightly stained.

3. **Osteoclasts** are bone destroying cells and take part during growth and remodelling. They are large multinucleated giant cells about 100μ with pale foamy cytoplasm. Osteoclasts arise by fusion of osteoblasts or by fusion of undifferentiated mesenchymal cells in the bone marrow.

Microspic features

A. Periosteum

Periosteum is a vascular fibrous membrane covering bones except on articular surfaces and consists of two layers:—

(a) an outer *fibrous layer* containing many periosteal blood vessels.

(b) an inner *osteogenic layer* containing osteoblasts which from bone.

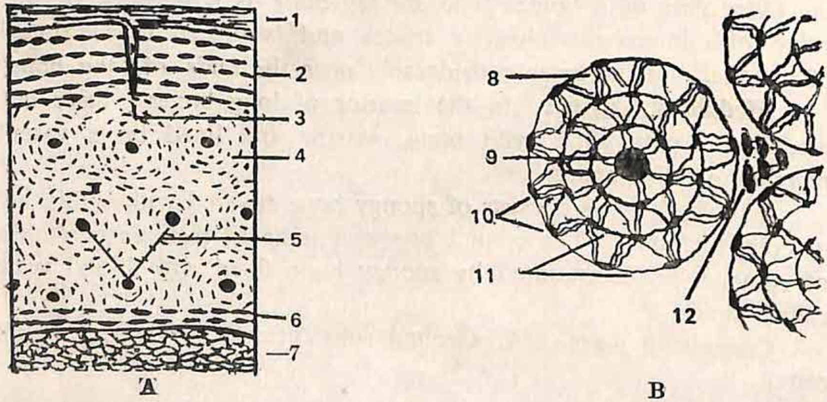


Fig. 16. A. Compact bone (T.S.): 1. Periosteum. 2. Periosteal lamellae, 3. Perforating fibres of Sharpey, 4. Haversian system, 5. Volkmann's canal, 6. Endosteal lamellae, 7. Bone marrow, B. Haversian system (detail) ; 8. Canaliculi, 9. Haversian canal, 10. Osteocytes in lacunae, 11. Lamellae, 12. Interstitial lamellae.

Periosteum is united to the underlying bone by *perforating fibres of Sharpey*.

B. Compact Bone

Compact bone consists of cylindrical units called *osteones* or *Haversian systems* comprising—

1. *Haversian canals*: These are little tubes located in the centre of Haversian systems, run parallel to the long axis of the bone, and are united to other canals by side branches. They contain blood vessels, nerves and lymphatics.

2. *Concentric bony lamellae* surround the Haversian canal. The lamellae consist of fine collagen bundles in calcified matrix.

3. *Lacunae* are small oval spaces on the lamellae and contain cell bodies of osteocytes.

4. *Canaliculi* are fine radiating channels connecting lacunae and contain processes of osteocytes and nutritive fluid.

5. *Osteocytes* are located in the lacunae and their processes extend into canaliculi.

6. *Interstitial lamellae* containing lacunae and canaliculi lie between osteones. Periosteal and endosteal lamellae are parallel lamellae lying next to periosteum and endosteum respectively.

Volkmann's canals are vascular canals containing blood vessels, and connect Haversian canals with periosteum and marrow cavity. They are not surrounded by bony lamellae.

C. Spongy Bone

The lamellae are irregularly arranged and there are no osteones.

D. Sesamoid Bone

Develops in tendons (e.g., patella) or ligaments. They have no periosteum, no osteones and no medullary cavity.

E. Bone Marrow

Bone marrow is the soft vascular tissue located in the medullary cavity and the spaces between the trabeculae of spongy bone.

Types: Red and yellow (Fatty) marrow.

Red marrow is blood cell forming marrow; it forms RBC, WBC and platelets. Yellow marrow is mostly fat.

At birth all marrow of all bones are red. As age advances the red marrow is partly replaced by yellow marrow. This change begins at about 7th year from the distal ends of long bones. In young adult, in long bones red marrow is present only in the upper ends of femur and humerus. Ribs, sternum, skull bones, vertebrae, clavicles, scapulae and hip bones contain red marrow throughout life.

Structure of red marrow (see Myeloid tissue in Blood, p. 44).

Blood supply:

Bone has rich blood supply mainly from *nutrient* and *periosteal* arteries. Most of the arterioles end in sinusoids. Veins have no valves.

Arterial supply of long bone: 1. *Nutrient Artery*: Supplies the marrow and inner part of compact bone. It enters the nutrient foramen and as it passes through compact bone, it sends branches to Haversian canals. On reaching the marrow cavity it divides into ascending and descending branches (arteria nutritiae); each divides into a leash of parallel branches, which run to metaphysis.

2. *Periosteal Arteries*: Supply the compact bone of shaft. They pass along the attachment of muscles. These arteries are absent in bare areas where there are no muscular attachments, e.g., lower 1/3 of tibia. Fractures at these sites may cause delayed union or non-union.

3. & 4. *Epiphyseal Arteries*: Supply the ends of long bones.

Development (Ossification) of Bone:

Bone is mesodermal and develops from mesenchyme. Areas from which bone formation begins are called *centres of ossification.*

Types: *Intramembranous B. Intracartilaginous.*

A. In **Intramembranous ossification** the mesenchyme is directly converted into bone. The mesenchymal cells become osteoblasts which produce collagen fibres and hyaline matrix. Finally calcium salts are deposited. The surrounding mesenchyme becomes periosteum. Ossification extends radially by surface osteoblasts.

Ex: clavicle, skull cap.

B. In **Intracartilaginous ossification** the mesenchyme is first converted into little models of hyaline cartilage. In the next phase the cartilage is completely destroyed bit by bit and is replaced by bone.

Process:

1. The cartilage cells in the middle of the cartilage model enlarge, manufacture alkaline phosphatase and there is deposition of calcium salts. Nutrition to cartilage cells is shut off, they die and disintegrate.

The cartilage matrix also dissolves and leaves irregular cavities——*primary areolae.*

2. Formation of sleeve like subperiosteal bone by intramembranous method in the mid-third of cartilage model.

3. Formation of little rents (apertures) in the subperiosteal bone by the osteoclasts.

4. Invasion of *subperiosteal bud* (containing osteoblasts, osteoclasts and blood capillaries) from the deeper part of periosteum, through the apertures, to the central part.

5. Now osteoclasts erode the wall of primary areolae and convert them into big spaces termed *secondary areolae.*

6. The osteoblasts arrange themselves along the wall of secondary areolae, and produce collagen fibres and hyaline bone matrix, and subsequently calcium salts are deposited.

7. Thus the mid part of the shaft is converted into bone and the process gradually extends towards each end.

Periosteum continues to add bone to the sides of the model and at the same time the central part of cancellous bone is dissolved away and the marrow cavity is formed.

After birth, by similar process *epiphysis* is formed at the ends of long bones. The plate of hyaline cartilage between epiphysis and *diaphysis* is the *epiphyseal plate,* which contributes to diaphysis.

The epiphyseal cartilage cells multiply continually and are arranged in 4 zones : (i) zone of resting cartilage cells, (ii) zone of proliferating cartilage cells, (iii) zone of maturing cartilage cells and (iv) zone of calcified cartilage, in which cartilage cells die and disintegrate. Next is the zone of newly formed bone.

Bone increases in length till at least one epiphyseal cartilage persists. When whole cartilage is used up (destroyed) epiphysis and diaphysis unite. Henceforth no further elongation is possible.

Circumference of bone increases from the inner layer of periosteum ; at he same time absorption takes place from within, and medullary cavity enlarges.

Certain terms :

Diaphysis is the part of bone formed the primary centre of ossification and forms the shaft of long bones. The ends of diaphysis where active growth is taking place is called *metaphysis.*

Epiphysis is the part of bone formed from secondary centre of ossification and forms the ends and bony prominences of long bones.

Epiphysis is formed from the deeper parts of articular cartilage and not from epiphyseal cartilage.

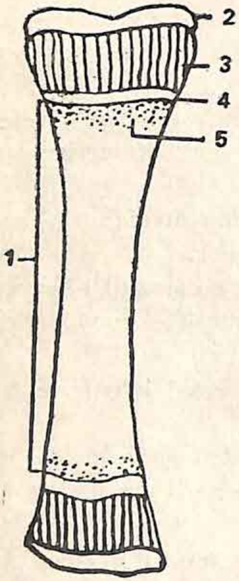


Fig. 17. Parts of developing long bone. 1. Diaphysis, 2. Articular cartilage, 3. Epiphysis, 4. Epiphyseal cartilage, 5. Metaphysis.

Laws of ossification

1. *Growing end of a bone* : When there are two epiphyseal cartilages, one at each end, growth is much faster and continues for a longer period at one end (constant for a particular bone)—that end is called the growing end of the bone.

2. Out of two secondary centres, the centre which appears early fuses late (exception—fibula).

3. *Direction of nutrient foramen*—away from growing end.

IV BLOOD

Blood is a specialized type of connective tissue in which the intercellular substance is a straw coloured fluid termed the *plasma*.

Quantity: 5 to 6 litres, about 7% of the body weight.

Component parts :

I *Formed elements* : 45%, A. Erythrocytes, B. Leucocytes. C. Platelets.

II *Plasma* : 55%, histologically plasma is invisible in sections: Serum is defibrinated plasma.

A. Erythrocytes (RBC)

In mammals RBC has no nucleus, no endoplasmic reticulum, no Golgi complex, no centrosome, no mitochondria, but contains the respiratory pigment haemoglobin.

Shape : Circular giconcave discs which increase the surface area.

Size : In dry smears 6.7 to 7.6μ (average 7.2μ).

Number : In males 5 to 6 (average 5.5) millions per cu. mm. of blood. In females 4 to 5 (average 4.5) millions per cu. mm. of blood.

Colour : A single RBC looks pale yellow ; in mass they appear red.

Life Span : About 120 days.

Function : (i) Carriage of Oxygen and Carbon dioxde ; (ii) Also helps in the regulation of Ph of blood. Deficiency of Haemoglobin causes anaemia.

Fate : Old and worn out RBC are injested and broken by the macrophages of spleen and liver sinusoids (i.e., by R.E.S.).

The haemoglobin is broken into 2 parts : globin & heme. Globin is further broken down to amino-acids. The iron from heme is stored in bone marrow and liver for further haemoglobin synthesis ; the non-iron part from heme is excreted as bile pigments (biliverdin and bilirubin).

Reticulocyte

Reticulocytes are immediate precursor of erythrocyte and less than 1% is present in peripheral blood. They possess a fine granular reticulum (remnant of rough endoplasmic reticulum of the precursor cells) rich in RNA, which are stained light blue with brilliant cresyl blue (supravital stain).

B. Leucocytes (WBC)

Leucocytes are colourless cells containing nuclei and are a little larger in size than the erythrocytes but much less in number (4000 to 11,000 per cu. mm. of blood). In smear preparation the cells become flattened and so appear larger than in life.

Classification

I *Granulocytes* containing specific granules in their cytoplasm. 1. Neutrophils, 2. Eosinophils, 3. Basophils.

II *Agranular Leucocytes* without granules in their cytoplasm. 1. Lymphocytes, 2. Monocytes.

Neutrophils (60 to 70%)

Size—9 to 12μ

Nucleus—Lobated, having 2 to 5 lobes. The lobes are connected by thin threads of chromatin. Number of lobes increases with age of the cell.

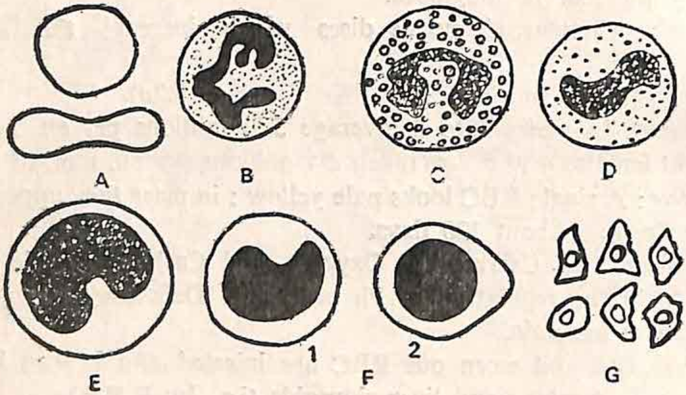


Fig. 18. Blood cells and platelets: A. RBC, B. Neutrophil, C. Eosinophil, D. Basophil, E. Monocyte, F. Lymphocyte—1. Large, 2. Small, G. Platelets.

Cytoplasm—contains fine granules and takes a light stain.

Life Span—About 60 hours.

Eosinophils (2 to 5%)

Size—12μ

Nucleus—With 2 to 3 lobes connected by thin chromatin thread.

Cytoplasm—Contains large number of coarse eosinophilic granules

Life Span—8 to 12 days.

Basophils (0 to 1%)

Size—10μ.

Nucleus—Somewhat bent, often S-shaped, chromatin network loosely arranged.

Cytoplasm—Contains very coarse basic metachromatic granules which often mask the nucleus.

Life span—12 to 15 days.

The mast cells of connective tissue resemble basophils but are distinct entity.

Lymphocytes (25 to 30%)

Size—Small lymphocytes 6-8μ; large lymphocytes 12-15μ.

Nucleus—Large, spherical but often indented on one side; very dense and dark due to heavy chromatin mass. Nucleoli present.

Cytoplasm—Thin rim of cytoplasm; it is basophilic and stains clear blue (clear-glass appearance). Some cells show a few non-specific azurophil granules.

Types of Lymphocytes: (based on immunologic competence and life span).

(*a*) *T-Lymphocytes* (*Thymus processed lymphocytes* form about 70% of circulating lymphocytes. They have long life counted in terms of years and are concerned with cell mediated immunological reactions.

(*b*) *B-Lymphocytes* (*Bursa lymphocytes*) form about 20% of circulating lymphocytes. They are short lived (several weeks or so) and are concerned with humoral antibody response (synthesis). B-lymphocytes transform into plasma cells which produce antibodies.

(*c*) *K-lymphocytes* (*Killer lymphocytes*) form 10% of lymphocytes. These are non-processed lymphocytes, and are immunologically incompetent but can gain competence in presence of antibody or antigen-antibody complexes.

Monocytes (2 to 8%)

Size—15 to 20μ.

Nucleus—Oval or kidney shaped, eccentric in position, less chromatin with delicate network than lymphocytes and thus the nucleus takes a lighter stain. Nucleoli present.

Cytoplasm—Plenty, basophilic and stains muddier blue (frosted-glass appearance).

C. Blood Platelets (Thrombocytes)

Platelets are non-nucleated tiny cytoplasmic fragments.

Shape—Round to oval.

Size—2 to 4μ.

Number—200,000 to 400,000 per cu mm. of blood.

Description—A central more basophilic region (chromomere), and a peripheral clear hyaline region (hyalomere).

Life span—3 to 5 days.

HEMOPOIESIS (DEVELOPMENT OF BLOOD CELLS).

There are two types of hemopoietic (blood forming) tissues:

A. Lymphoid Tissue

Comprises (i) Reticular fibres and primitive reticular cell; (ii) Lymphocytes in different stages of development and maturation. Lymphoid tissues form lymphocytes and some monocytes.

Chief lymphoid organs : Lymph nodes, Spleen, Thymus, Tonsil and scattered lymph nodules.

B. Myeloid tissue

Myeloid tissue is confined to red bone marrow. It comprises (i) Reticular framework consisting of reticular cells and fibres, (ii) Sinusoids, (iii) Marrow cells (Myeloid elements) consisting of various stages in the development of erythrocytes, leucocytes and platelets.

Blood cells are formed in the loose stroma of red marrow outside the blood stream, and become added to it when required.

Primitive reticular cell gives rise to *Haemocytoblast,* a large multipotent cell about 15μ with fairly abundant basophilic cytoplasm and a large nucleus with nucleoli. *Haemocytoblast is the stem cell and gives rise to erythrocytes, leucocytes and platelets.*

Development of RBC

RBC development is characterised by (i) Progressive reduction in cell size, (ii) Increasing content of haemoglobin, (iii) Shrinkage and loss of nucleus. The various stages in the development are :

Haemocytoblast — Proerythroblast — Normoblast — Reticulocyte Erythrocyte (R B C).

Development of Granulocytes

Granulocyte development is characterised by (i) Gradual reduction in cell size, (ii) Aquisition of specific cytoplasmic granules, (iii) Compactness and lobation of nucleus. The various stages in the development are :

Haemocytoblast — Myeloblast — Promyelocyte — Myelocyte — Metamyelocyte — Polymorph (Neutrophil, Eosinophil, Basophil).

Development of Agranular leucocytes

Lymphocytes : Arise from lymphoid tissue, and some from bone marrow. The precursor cell is the lymphoblast. Possibly all stem cells arise from bone marrow early in foetal life, and settle in thymus and other lymphoid organs.

Monocytes : Arise chiefly from spleen and other lymphoid tissues, and to a lesser extent from bone marrow. Monoblast is the precursor cell, resembling myeloblast.

Development of platelets

Haemocytoblast-megakaryoblast-megakaryocyte (large giant cell of the bone marow measuring over 40μ and contains an irregularly lobated nucleus)—*Platelets* arise by nipping off the cytopalsm of megakaryocytes.

5 Muscular Tissue

Muscle is a tissue specialized for producing movements. The structural and functional unit of muscle is a *muscle fibre*, which is an elongated cell. It contains contractile fibrils termed *myofibrils* embedded in its cytoplasm called *sarcoplasm*. Muscle develops from mesoderm except some smooth muscles, namely muscles of iris and myoepithelial cells which are ectodermal.

Classification

Smooth muscle }
Cardiac muscle } Involuntary and supplied by autonomic nerves.
Skeletal muscle—voluntary and innervated by somatic nerves.

I SMOOTH MUSCLE

Synonyms : Plain, non-striped, involuntary.

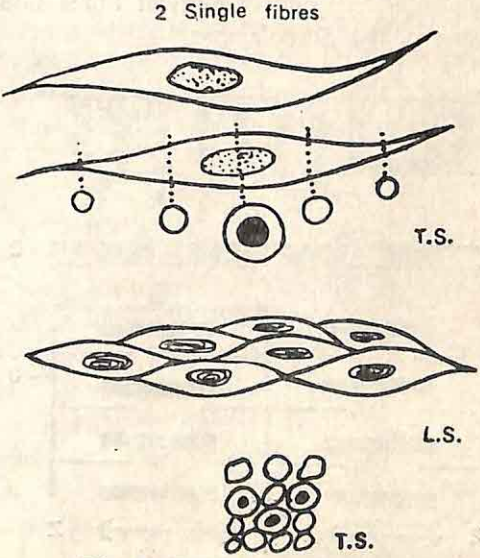


Fig. 19 Smooth muscle.

Shape : Long spindle shaped cells tapering at both ends and covered by a thin plasma membrane.

Size : Length 20 to 200μ; greatest diameter about 6μ; the size increases greatly when required e.g., the muscles of uterus during pregnancy (from 50 to 500μ).

Nucleus : Single, oval or rod-shaped, central in position. In contracted condition of muscle the nucleus may become wrinkled.

Cytoplasm (Sarcoplasm) : Homogeneous in living state ; after proper staining it shows faint longitudinal striations due to longitudinally placed myofibrils. Each myofibril consists of groups of myofilaments which comprise of two proteins—*actin* and *myosin.*

Nexus: are areas where adjacent smooth muscle fibres come in close contact and there is fusion of plasma membrane. Nexus helps in the spread of excitation from one cell to another.

Chief distribution : Blood vessels, gastro-intestinal canal, genital and urinary passages, ducts, dartos muscle, ciliary muscle, muscle of iris, arrectores pilorum.

Myoepithelial cells

These are modified epithelial cells of ectodermal origin, containing myofibrils in their cytoplasm. Their shape varies from spindle shaped to branched cells, and are located in the alveoli between the basal lamina and the secreting cells. They contract to empty the alveoli.

Distribution : In sweat gland, mammary gland, lacrimal gland, and basket cells of salivary glands.

II SKELETAL MUSCLE

Synonyms : voluntary, striated.

Shape : Long cylindrical fibres bounded by a tough cell membrane called *Sarcolemma*.

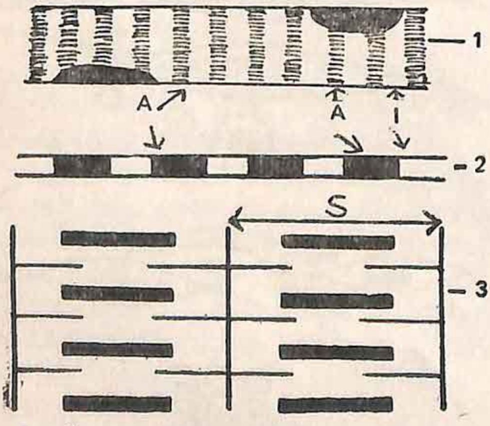


Fig. 20. Skeletal muscle: 1. Muscle fibre, 2. Myofibril, 3. Myofilaments. A. Dark band, I-light band, Z-Z-line, S-Sarcomere.

Size : Length usually ranges from 1 to 40 mm. but may be 30 cm. or more e.g., Sartorius; diameter varies from 10 to 100μ.

Nuclei: Multinucleated; may be several hundred nuclei in a single large fibre. *The nuclei are oval in shape and situated at the periphery.*

Cytoplasm (*sarcoplasm*) : Contains myofibrils, mitochondria (sarcosomes) Golgi complex and sarcoplasmic reticulum. *Each muscle fibre shows cross striations of alternate dark* (*A*) *and light* (*I*) *bands.*

Myofibril

Each muscle fibre contains large number of *myofibrils*, which are thread like structures running parallel to one another within the entire length of the muscle fibre. The myofibrils are often grouped in small bundles, which in T.S. are termed *Cohnheim's area*.

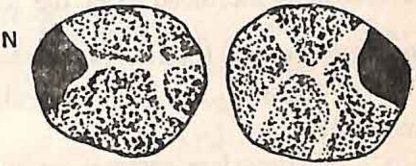


Fig. 21. T.S. of 2 skeletal muscle fibres showing Cohnheim's areas: N-nucleus.

Each myofibril is striated, and exhibits along its length alternate dark (Anisotropic or A bands) and light (Isotropic or I bands) bands of nearly equal thickness 1 to 2 microns. The dark bands have greater affinity for basic dyes than the light bands. The corresponding bands of all fibrils in a fibre align at the same levels. As such L.S. or teased preparation of skeletal muscle fibres show cross-striations.

Myofilaments

Each myofibril contains two types of myofilaments (i) long and thin *Actin* filaments and (2) short and thick *Myosin* filaments. These filaments are arranged in parallel arrays with even spaces.

The *I band* contains only actin (fine) filaments, which are attached to Z - disc (line) situated in the middle of I band.

The A band has two parts: (a) central part (*H band*) containing only myosin (thick) filaments ; m-line is a thickening in the centre of H band. (b) Lateral parts containing both thick and thin filaments. In cross section 6 thin filaments surround one thick filament, whereas 3 thick filaments are triangularly arranged around 1 thin filament.

Sarcomere is the portion of myofibril between two successive Z-lines.

Sarcoplasmic Reticulum (Specialized endoplasmic reticulum): It is an elaborate system of membrane bound tubules that surround each myofibril and extend between two successive Z-lines. Near Z-lines the tubules expand transversely forming the terminal cistern. Also at the Z-line a T-tubule is formed by tube like infolding of the sarcolemma.

Mechanism of contraction: The T-tubule conducts the excitation inwards and then causes the Sarcoplasmic reticulum to release calcium ions, which causes contraction of myofilaments.

During contraction, the thin filaments slide into the intervals between thick filaments and pull the attached Z-discs with them. The length of I-band diminishes progressively. At full contraction the free ends of fine filaments meet and obliterate the H-band. Thus the entire muscle is shortened; but the length of A-band remains constant.

Connective tissue framework of skeletal Muscle

1. *Endomysium* is the vascular areolar tissue surrounding each muscle fibre.
2. *Perimysium* encloses groups of muscle fibres termed *fasciculi.*
3. *Epimysium* invests the muscle as a whole.

Distribution :

Besides muscles attached to skeleton, skeletal muscle is found in tongue, pharynx. upper 2/3rd of oesophagus, anal canal and lower part of vagina.

N.B. Small skeletal muscle fibres within the neuromuscular spindles are called *Intra-fusal fibres.* Most of the skeletal muscle fibres lie outside the spindle and are termed *Extra-fusal fibres.*

Nerve Supply

Extra-fusal fibres receive large myelinated alpha nerve-fibres. Intra-fusal fibres receive : (i) Motor fibres (fine myelinated Gamma fibres) at the polar regions, and (ii) Sensory fibres at the central region.

III CARDIAC MUSCLE

The cardiac muscle resembles in structure to skeletal muscle, in development and innervation to smooth muscle, and in function to both. It contracts rapidly, rhythmically, tirelessly and endlessly from embryonic life until death.

Shape & Size : Short cylindrical cells placed end to end. The cells branch and anastomose freely to form a pseudo-syncitium (meshwork).

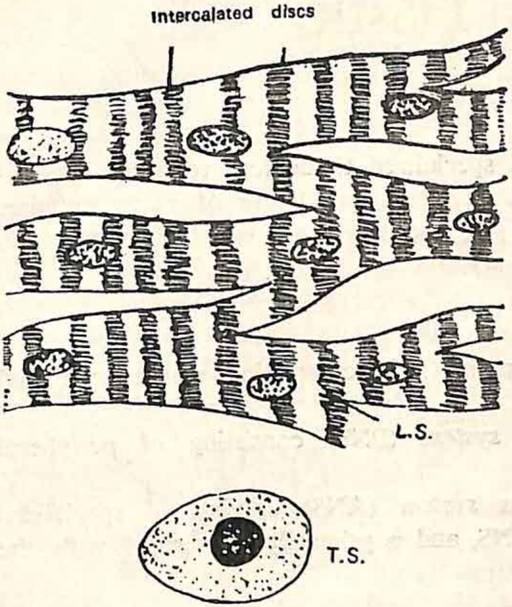


Fig. 22. Cardiac muscle.

Sarcolemma: Thinner than skeletal muscle.

Nucleus: Usually single, oval and placed in the centre of the cell.

Sarcoplasm: Contains faint transverse striations of alternate dark (A) and light (I) bands of myofibrils. The sarcoplasmic reticulum is less prominent, but T-tubules are prominent at the Z-lines.

Intercalated Discs

These are cell membrane junctions between adjacent cardiac muscle cells and pursue a zigzag course. They are well stained by silver salts.

Impulse Conducting System (Purkinje Fibres) are modified cardiac muscle fibres having large cells with relatively more sarcoplasm and less myofibrils. The Purkinje fibres have their own inherent beat, conduct cardiac impulse and co-ordinate the atrial and ventricular beats.

MUSCLE REGENERATION AND REPAIR

Smooth muscle regenerates to a small extent. In skeletal muscle, new fibres are not formed. Remnants of injured fibres can regenerate povided nuclei with surrounding sarcoplasm remains alive. In cardiac muscle regeneration is insignificant. In all muscles, healing is by formation of connective tissue scar.

6 Nervous Tissue

The nervous tissue is a specialized tissue for reception of stimuli, for generation, conduction and correlation of nerve impulses so that suitable responses may occur. It is ectodermal in origin except microglia (mesodermal).

Subdivisions of nervous system (NS)

(*a*) *Central nervous system* **(CNS)** comprising spinal cord and brain.

(*b*) *Peripheral nervous system* **(PNS)** consisting of peripheral nerves and ganglia.

(*c*) *Autonomic nervous system* **(ANS)** consists of specialized portions of both CNS and PNS, and is primarily concerned with the regulation of visceral activities.

Component Parts of NS :

I. Neurons, **II. Supporting cells.**

I. NEURONS

A neuron is the structural and functional unit of NS composed of a cell body and one or more processes. The processes are the *axon* and *dendrite*. Each neuron has only one axon, while the dendrite may be one or many. Most nerve cell bodies are present within the CNS. Collections of nerve cells outside the CNS are termed *ganglia*.

Classification of Neurons

A. On the basis of number of processes :

1. *Unipolar neurons* : possess *only one process*, e.g., developing neuroblasts, mesencephalic nucleus of V nerve.

2. *Pseudo-unipolar neurons* : A *single process* arises from spherical cell body, whch splits into two like the letter T e.g., all sensory ganglia except vestibular and cochlear ganglia.

3. *Bipolar neurons* : ***Two processes,*** **an axon and a dendrite.** are attached to the opposite ends of a spindle-shaped cell body, e.g., Olfactory neuro-epithelium, Cochlear and vestibular ganglia, Inner and Outer nuclear layers of retina.

4 *Multipolar neurons* : *Many processes* (one axon and many dendrites) arise from the cell body, e.g., Neurons in CNS and autonomic ganglia.

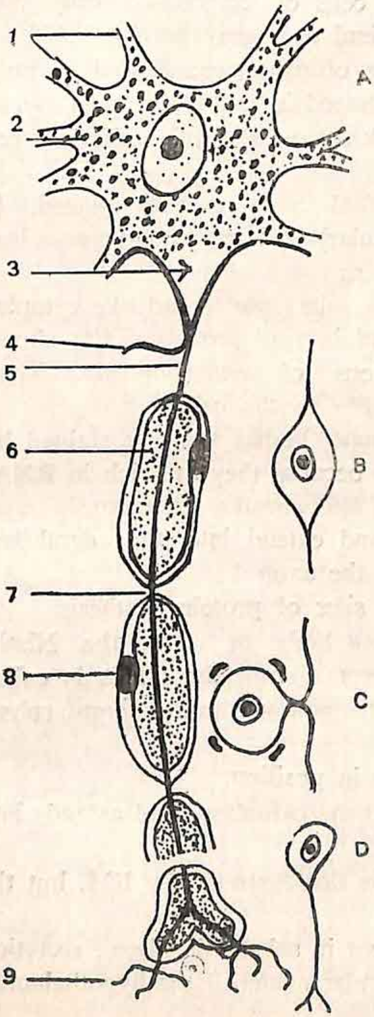


Fig. 23. Types of nerve cells, and L.S. of a myelinated nerve fibre: A. Multipolar neuron, B. Bipolar neuron, C. Pseudo-unipolar neuron, D. Unipolar neuron. 1. Dendrites, 2. Nissl's granules, 3. Axon hillock, 4. Collateral, 5. Axon, 6. Myelin sheath, 7. Node of Ranvier, 8. Sheath of Schwann with nucleus, 9. Axon terminal.

B. On the basis of axon length **:**

1. *Golgi type I* neurons have long axons which form fibre tracts

within CNS, or pass out of it as peripheral nerves e.g., Tract cells, Alpha cells of anterior horn of spinal cord.

2. *Golgi type II* neurons have short axons and lie within CNS and mostly form association fibres.

Structure of Neuron

A. Cell Body (Perikaryon)

Size: Very variable. Granule cells of cerebellum only 5μ, Alpha cells in the anterior horn of spinal cord may be about 130μ.

Shape: Depends on the number of processes: Round in unipolar cells, oval in bipolar cells, star-shaped in multipolar cells, pyramidal cells in cerebral cortex, and flask shaped Purkinje cells in cerebellum.

Nucleus: Relatively large, spherical and centrally placed. It appears pale and empty looking (vesicular) with prominent nucleolus.

Cytoplasm (Neuroplasm): Contains:

1. *Neurofibrils* (stained by silver salts) are thread like cytoplasmic fibrils in the cell body and extend into all processes. EM shows each neurofibril to consist of collections of *neurofilaments*. They provide mechanical support and stability to the cell.

2. *Nissl's bodies* are small granular bodies that are stained by basic aniline dyes (e.g. toluidine blue) because they are rich in RNA. EM shows them to be rough surfaced endoplasmic reticulum.

Location: Present in cell body and extend into the dendrites, but are absent from axon hillock and the axon.

Function: Nissl's bodies are the sites of protein synthesis.

Chromatolysis: After injury to cell body or axon, the Nissl's bodies degenerate and disappear almost completely. This is called *chromatolysis*. On regeneration of the neuron they undergo subsequent reconstitution.

3. *Golgi complex* is perinuclear in position.

4. *Mitochondria* are scattered in the cytoplasm and extends into all processes.

5. An inconspicuous *centriole* is demonstrated by EM, but the *adult nerve cells do not divide.*

6. *Inclusions* e.g. Melanin pigment in substantia nigra ; secretion granules in supraoptic and paraventricular nuclei of the hypothalamus.

B. Axon (Axis Cylinder)

Each neuron has only one axon and arises from the cell body from a small conical elevation called *axon hillock*. The axon is long, slender and less branched ; **branches** termed *collaterals* arise at right angles. The terminal branches are known as *axon terminals* or *telodendria.* The axon is bounded by *axolemma*, and its *axoplasm* contains neurofibrils, mitochondria but is devoid of Nissl's bodies. Normally an axon carries nerve impulses away from the cell body.

C. Dendrite

One or many, are afferent processes of the neuron. They are short, thick and branch profusely like a bush. Their internal structure is similar to the cell body except the nucleus. Usually the dendrites carry nerve impulses **towards** the cell body, Long dendrites of sensory ganglia have a structure similar to the axons of these cells.

Nerve Fibres

A nerve fibre consists of the axon or dendrite with its coverings derived from ectoderm.

Classification of Nerve Fibres

A. On the basis of myelin sheath.

1. *Myelinated* (Medullated), 2. *Unmyelinated* (Non-medullated) and 3. *Naked nerve fibres.*

1. Myelinated Nerve Fibres

(a) In *Peripheral Nervous System*

Example : Cranial and spinal nerves (except some sensory fibres). Preganglionic autonomic fibres.

Structure : (See Figs. 23 & 24).

(i) *Axis cylinder* forms the central core of nerve fibres.

(ii) *Myelin sheath covers the axis cylinder. Myelin* is a lipoprotein complex containing unsaturated fatty acids. In fresh condition it is white and shiny, *but stains black with osmium tetroxide.* In PNS myelin is formed by the rotation of Schwann cell around the axon in a spiral manner. EM shows that myelin is composed of concentrically arranged lamellae with alternating series of thick (*major dense lines*) and thin (*intraperiod lines*) dark lines. It is an insulating material and increases conduction speed.

Nodes of Ranvier (seen in L. S. and in teased preparations only) : The myelin sheath is interrupted at regular intervals by constrictions termed the *nodes of Ranvier*. The internodal distance comprises one cell of Schwann ; thus the node of Ranvier is the junction between two

Schwann cells. The nodes of Ranvier accelerates conduction speed. Incisures of Schmidt Lanterman are little oblique clefts in myelin.

(iii) *Sheath of Schwann* is a delicate transparent membrane composed of Schwann cells and lies outside the myelin sheath. It provides nutrition to the axon.

In PNS each myelinated fibre is covered by a mesodermal connective tissue sheath, the endoneurium.

(b) In *Central Nervous System*

Example : Fibre tracts of brain and spinal cord.

Structure :

(i) Axis cylinder.

(ii) Myelin sheath with nodes of Ranvier. *Myelin in CNS is formed from oligodendrocytes.*

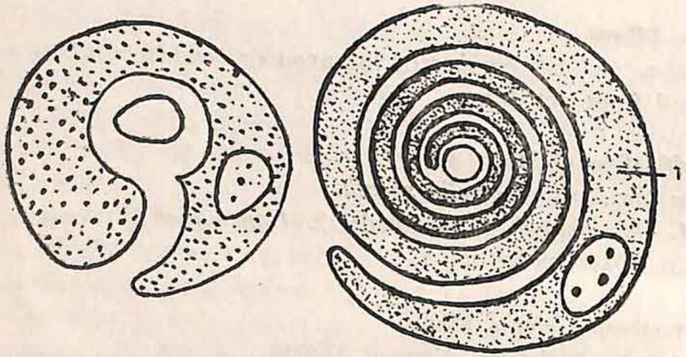


Fig. 24. Two stages in the development of myelin sheath in Peripheral nerve. 1—Schwann cell.

(iii) Rows of oligodendrocytes (in place of Schwann cells). In CNS there is absence of Schwann cells and endoneurium.

2. Unmyelinated Nerve Fibres

(a) In *Peripheral Nervous System*

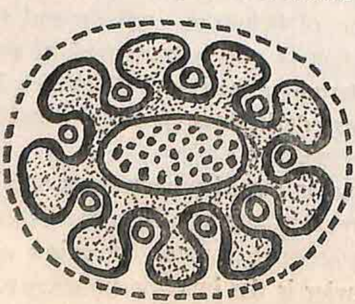


Fig. 25. Nine Unmyelinated nerve fibres in gutters of a single Schwann cell.

Example: Postganglionic autonomic fibres.

Structure (Fig. 25) : In unmyelinated fibres many axons are enclosed in a single Schwann cell. Thus sheath of Schwann is found in all peripheral nerves, myelinated or unmyelinated. Outside the Schwann cell is the endoneurium.

(b) In *Central Nervous System*

Example : Small axons and dendrites.

Structure : The unmyelinated fibres have only Scattered oligodendrocytes.

3. Naked Nerve Fibres

As the nerve fibre approaches its termination, the myelin sheath and then the sheath of Schwann disappears and the nerve fibre becomes naked.

B. On the basis of diameter of fibres and the rate of conduction of nerve-impulses, the peripheral nerves are classified into :

1. Type A fibres—Thickest fibres with highest speed e.g., somatic efferent fibres.
2. Type B fibres—Medium sized fibres with moderate speed e.g., myelinated preganglionic fibres.
3. Type C fibres—Thinnest with slow speed e.g., post-ganglionic autonomic fibres.

Nerves (Nerve Trunks)

A nerve trunk comprises of groups (bundles) of nerve fibres bound together by connective tissue. Each bundle is called a *funiculus*. A smaller nerve may contain only one funiculus.

T. S. of NERVE TRUNK (Fig. 26)

1. *Epineurium* is a connective tissue sheath enclosing the nerve trunk as a whole.
2. *Perineurium* is a dense connective tissue sheath surrounding each funiculus.
3. *Endoneurium* is a thin connective tissue sheath covering each nerve fibre. Internal to endoneurium lies the sheath of Schwann, *myelin sheath* (seen as black rings when stained by osmic acid) and the axon.

Ganglia

A ganglion is a collection of nerve cells located outside the CNS.

Classification :

A. Sensory Ganglia (Ganglia of Conduction)

All sensory ganglia contain unipolar neurons except vestibular and Cochlear ganglia, which are bipolar cells. Each ganglion has a thin connective tissue capsule within which the nerve cells are peripherally placed. Each ganglion cell is surrounded by a single layer of flattened satellite cells.

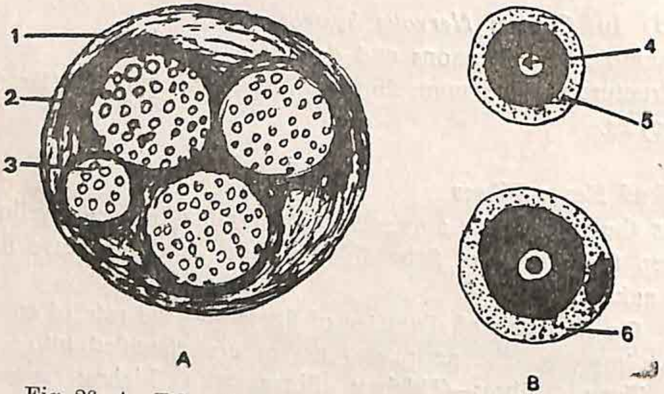


Fig. 26. A. T.S. of nerve trunk showing 4. funiculi: 1. Epineurium, 2. Perineurium, 3. Endoneurium. B. T.S. of two myelinated nerve fibres: 4. Axon, 5. Myelin sheath, 6. Sheath of Schwann with nucleus.

B. Motor (Autonomic) ganglia (Ganglia of synapse) :

Autonomic ganglion cells are multipolar, smaller and scattered uniformly. Each cell is surrounded by a few satellite cells. The axons of preganglionic neurons make synaptic contacts with the dendrites and cell bodies of ganglion cells.

II. SUPPORTING TISSUE OF NS

- Within CNS–
  - Neuroglia
    - Astrocytes
    - Oligodendrocytes
    - Microglia
  - Ependyma
- **In PNS**
  - Schwann cells
  - Satellite cells

Astrocytes

They are star shaped cells with profuse branching processes and contain round or oval nucleus.

Types: Protoplasmic and Fibrous.

The *protoplasmic astrocytes*, mostly present in grey matter, have fairly thick processes, which contain granular cytoplasm. Many of these processes are attached to piamater, some extend to blood vessels and are termed *perivascular feet* (*sucker feet*).

The *fibrous astrocytes*, mostly confined to white matter have thin and long processes, some of which are attached to capillaries by perivascular feet.

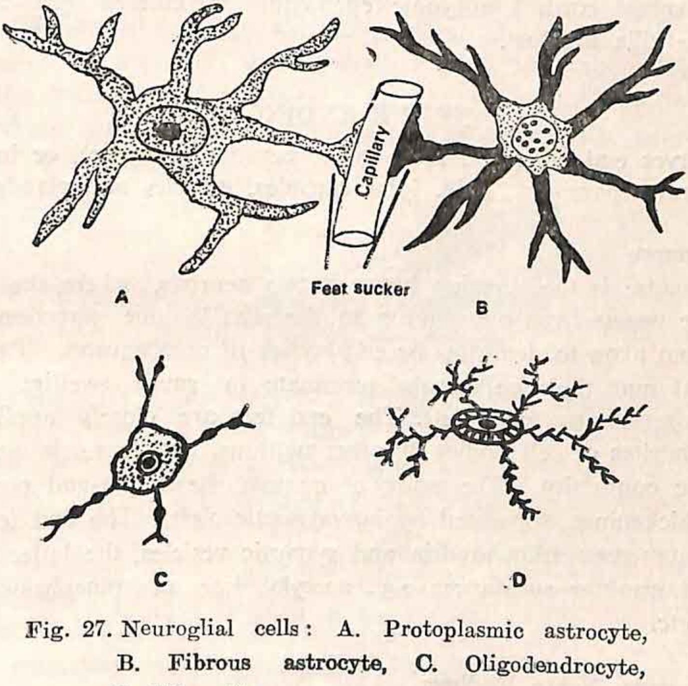


Fig. 27. Neuroglial cells: A. Protoplasmic astrocyte, B. Fibrous astrocyte, C. Oligodendrocyte, D. Microglia.

Function: Astrocytes give support, nutrition, and have some insulating functions as well. They also provide a special limiting membrane around the blood vessels (Blood brain barrier).

Oligodendrocytes

They are small cells with small fairly dense nucleus, scanty

Classification :

A. Sensory Ganglia (Ganglia of Conduction)

All sensory ganglia contain unipolar neurons except vestibular and Cochlear ganglia, which are bipolar cells. Each ganglion has a thin connective tissue capsule within which the nerve cells are peripherally placed. Each ganglion cell is surrounded by a single layer of flattened satellite cells.

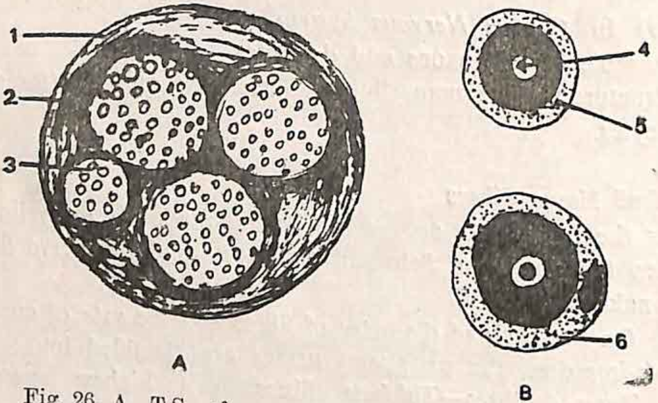


Fig. 26. A. T.S. of nerve trunk showing 4. funiculi: 1. Epineurium, 2. Perineurium, 3. Endoneurium. B. T.S. of two myelinated nerve fibres: 4. Axon, 5. Myelin sheath, 6. Sheath of Schwann with nucleus.

B. Motor (Autonomic) ganglia (Ganglia of synapse) :

Autonomic ganglion cells are multipolar, smaller and scattered uniformly. Each cell is surrounded by a few satellite cells. The axons of preganglionic neurons make synaptic contacts with the dendrites and cell bodies of ganglion cells.

II. SUPPORTING TISSUE OF NS

- Within CNS–
  - Neuroglia
    - Astrocytes
    - Oligodendrocytes
    - Microglia
  - Ependyma
- **In PNS**
  - Schwann cells
  - Satellite cells

Astrocytes

They are star shaped cells with profuse branching processes and contain round or oval nucleus.

Types : Protoplasmic and Fibrous.

The *protoplasmic astrocytes,* mostly present in grey matter, have fairly thick processes, which contain granular cytoplasm. Many of these processes are attached to piamater, some extend to blood vessels and are termed *perivascular feet* (*sucker feet*).

The *fibrous astrocytes,* mostly confined to white matter have thin and long processes, some of which are attached to capillaries by perivascular feet.

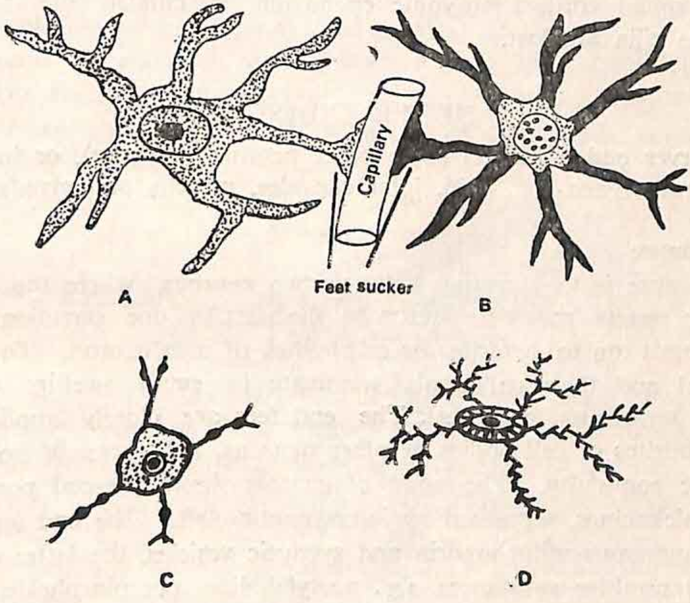


Fig. 27. Neuroglial cells : A. Protoplasmic astrocyte, B. Fibrous astrocyte, C. Oligodendrocyte, D. Microglia.

Function: Astrocytes give support, nutrition, and have some insulating functions as well. They also provide a special limiting membrane around the blood vessels (Blood brain barrier).

Oligodendrocytes

They are small cells with small fairly dense nucleus, scanty

Classification :

A. Sensory Ganglia (Ganglia of Conduction)

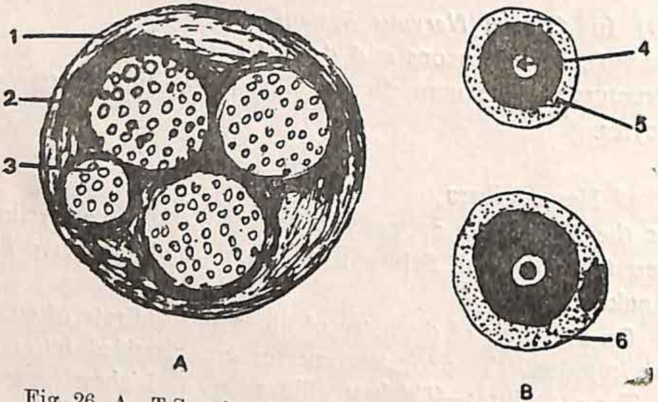


Fig. 26. A. T.S. of nerve trunk showing 4. funiculi: 1. Epineurium, 2. Perineurium, 3. Endoneurium. B. T.S. of two myelinated nerve fibres: 4. Axon, 5. Myelin sheath, 6. Sheath of Schwann with nucleus.

All sensory ganglia contain unipolar neurons except vestibular and Cochlear ganglia, which are bipolar cells. Each ganglion has a thin connective tissue capsule within which the nerve cells are peripherally placed. Each ganglion cell is surrounded by a single layer of flattened satellite cells.

B. Motor (Autonomic) ganglia (Ganglia of synapse):

Autonomic ganglion cells are multipolar, smaller and scattered uniformly. Each cell is surrounded by a few satellite cells. The axons of preganglionic neurons make synaptic contacts with the dendrites and cell bodies of ganglion cells.

II. SUPPORTING TISSUE OF NS

- Within CNS–
  - Neuroglia
    - Astrocytes
    - Oligodendrocytes
    - Microglia
  - Ependyma
- In PNS
  - Schwann cells
  - Satellite cells

Astrocytes

They are star shaped cells with profuse branching processes and contain round or oval nucleus.

Types : Protoplasmic and Fibrous.

The *protoplasmic astrocytes,* mostly present in grey matter, have fairly thick processes, which contain granular cytoplasm. Many of these processes are attached to piamater, some extend to blood vessels and are termed *perivascular feet (sucker feet).*

The *fibrous astrocytes,* mostly confined to white matter have thin and long processes, some of which are attached to capillaries by perivascular feet.

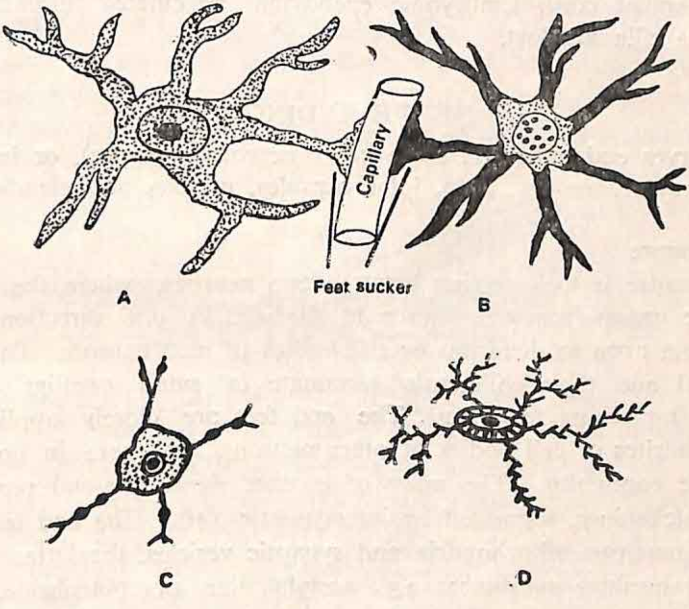


Fig. 27. Neuroglial cells : A. Protoplasmic astrocyte, B. Fibrous astrocyte, C. Oligodendrocyte, D. Microglia.

Function: Astrocytes give support, nutrition, and have some insulating functions as well. They also provide a special limiting membrane around the blood vessels (Blood brain barrier).

Oligodendrocytes

They are small cells with small fairly dense nucleus, scanty

cytoplasm and few processes; present in both grey and white matter. In grey matter they form **Satellite cells** to nerve cells.

Function : Oligodendrocytes form myelin sheath in CNS.

Microglia (Gitter Cells)

Microglia are small cells with small dark nucleus and scanty cytoplasm; the processes are beset with throny projections. They are *mesodermal in origin.*

Function : Phagocytosis (Macrophages of CNS).

Ependyma (Ependymal epithelium)

Ependyma lines the ventricles of the brain and the central canal of the spinal cord. Embryonic ependyma is ciliated (non-motile), later the cilia are lost.

NERVE ENDINGS

Nerves end either on some other neurons (Synapse), or in some peripheral organs e.g., Skin, joint capsules, muscles and glands.

A. Synapse

Synapse is the junction between two neurons, where the nerve impulse passes from one neuron to the next in one direction only, i.e., from axon to dendrites or cell bodies of next neuron. The axon terminal and their collaterals terminate in small swelligs termed bouton terminaux (end feet). The end feet are closely applied to the dendrites or cell bodies of other neurons, but there is no cytoplasmic continuity. The point of contact shows pre-and post-synaptic thickenings, separated by intersynaptic cleft. The end feet contains numerous mitochondria and synaptic vesicles, the latter contain neurotransmitter substances e.g., acetylcholine, norepinephrine, dopamine etc.

B. Sensory Nerve Endings

The sensory nerve endings are formed by the terminal parts of the sensory nerves. These endings are :

(a) Free (naked) nerve endings: Devoid of myelin and Schwann sheaths. They receive pain and tactile sensations. Free nerve endings in relation to hair follicles (peritrichial arborisations) receive touch stimuli.

(b) Encapsulated nerve endings : The terminations of naked nerve fibres are enclosed by a capsule of connective tissue. The various types are :—

1. *Pacinian corpuscle* : The capsule consists of concentrically arranged lamellae like the leaves of an onion. It receives pressure and proprioceptive stimuli.
2. *Meissner's corpuscle* : Receives tactile stimuli.
3. *Bulb of Krause*: Receives cold sensation.
4. *Organ of Ruffini* : Receives warm sensation.
5. *Neuromuscular spindle* : Consists of few modified skeletal muscle fibres (intrafusal fibres) enclosed in a connective tissue capsule and give information about the length of muscle. The intrafusal fibres are supplied both by motor (gamma efferents) and sensory fibres.
6. *Neurotendinous organ* of Golgi functions as tension recorders.

C. Motor Nerve Endings :

1. Motor end plate (in skeletal muscle) consists of two parts, a nervous and a muscular, separated by a tiny cleft ; the relationship is a close apposition of axolemma and sarcolemma. The *muscle part* is called *sole* where the sarcolemma forms gutters, which in turn give rise to secondary clefts called *subneural elefts*. The *neural part* : the naked axon terminals form little swellings which fit into the gutters and contain several mitochondria and vesicles. Teloglia cells (Non-myelinating Schwann cells) cover the gutters like lids. Endoneurium is prolonged over the nerve terminal to the surface of the muscle fibre and seem to fuse with the endomysium. Acetylcholine is the transmitter substance at the motor end plate.

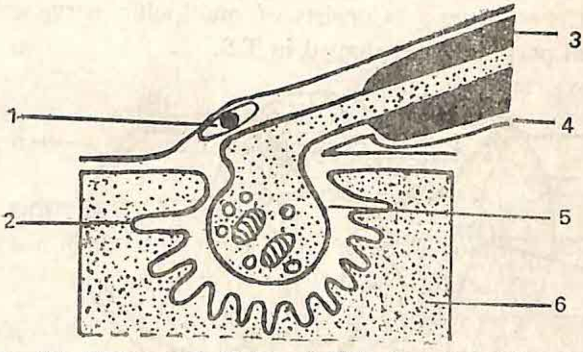


Fig. 28. Motor end plate: 1 Tologlia, 2. Sub-neural cletfs, 3. Myelin sheath, 4. Endoneurium, 5. Axon terminal, 6. Sarcoplasm.

2. In cardiac and smooth muscles, the non-myelinated fibres end by one or more terminal knobs on the plasma membrane, where as in gland cells they end among the epithelial cells.

CENTRAL NERVOUS SYSTEM

Grey Matter and White Matter : CNS is composed of grey matter and white matter, both supported by neuroglia. The grey matter mainly consists of multipolar nerve cells ; the white matter consists of myelinated nerve fibres.

A. T.S. of Spinal Cord

1. Covering of *piamater*.

2. Presence of *anterior median fissure* and *posterior median sulcus and septum*, which divide the spinal cord incompletely into right and left halves.

3. *White matter* and *grey matter* supported by neuroglia.

(a) *White matter* : Located in the peripheral part and consists of bundles of myelinated nerve fibres. Each half is divided into posterior, lateral and anterior funiculi by the attachments of dorsal and ventral nerve roots.

(b) *Grey matter* : Consists of multipolar nerve cells, located in the central part and is H-shaped in T.S.

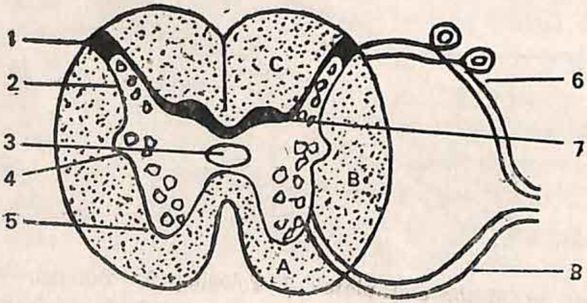


Fig. 29. T.S. of spinal cord. 1. substantia gelatinosa, 2. Dorsal horn, 3. Central canal, 4. Dateral horn, 5. Ventral horn, 6. Dorsal root with ganglion cels, 7. Clarke's column cell, 8. Ventral root.

(1) The transverse limb of the 'H' is termed *transverse grey commissure* and contains the central canal lined by ependyma, the canal contains cerebro-spinal fluid (C.S.F.).

(ii) Each half of the grey matter consists of anterior horn, posterior horn and an intermediate zone in between.

The *anterior horn* : Short and broad, directed forwards and laterally but does not reach the surface of the cord. It contains motor cells (alpha and gamma cells). The alpha cells give rise to ventral roots of spinal nerves.

The *posterior horn* : Narrow and elongated, directed backwards and laterally and reaches almost to the surface. It forms the sensory part of grey matter and contains small multipolar nerve cells. Its apex is capped by a gelatinous mass termed *substantia gelatinosa of Rolandi.* At the medial part of the base there is a well defined *nucleus dorsalis* (Clarke's column cell), which give rise to posterior spino cerebellar tract.

The *intermediate zone* presents the lateral horn from T_2 to L_1 segments. It contains small motor cells and gives rise to preganglionic sympathetic fibres. In $S_{2\ 3,\ 4}$ segments parasympathetic nuclei are present, and give rise to *pelvic splanchnic nerves..*

Regional differences : The shape and size of horns of grey matter vary at different levels but whatever their shape, the histological picture is the same.

B. Cerebellum

The cerebellum comprises : (a) surface layer of grey matter, the *cerebellar cortex,* (b) central core of *white matter*, (c) four pairs of *cerebellar nuclei* embedded in the white matter.

Cerebellar Cortex

Its structure is uniform in all parts of cerebellum and has 3 layers:

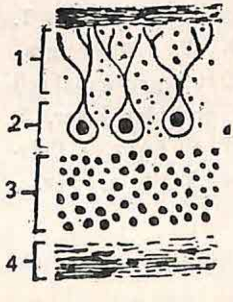


Fig. 30. Section of cerebellum : 1. Moelcular layer, 2. Purkinje cell layer, 3. Granular layer, 4. White matter.

1. *Outer molecular layer* contains many nerve fibres with few stellate cells and numerous deeply placed *basket cells.*
2. *Middle Purkinje cell layer forms a single layer of large flask*

shaped cells ; their dendrites pass into molecular layer while the axons pass through inner granular layer and mostly end in the cerebellar nuclei.

3. *Inner granular layer* contains closely packed small granule cells, their axons pass to outer molecular layer, while the dendrites make synaptic contacts with *mossy fibres.*

C. Cerebrum

The cerebrum comprises (a) surface layer of grey matter, the *cerebral cortex,* (b) central core of *whte matter*, (c) *Basal nuclei* embedded in white matter.

Cerebral Cortex :

Structure differs in different parts. The *neocortex* has six layers..

1. *Outer molecular layer* : Mostly nerve fibres derived from the dendrites of pyramidal and fusiform cells. Some horizontal cells of 'Cajal' and glial cells present.

2. *Outer granular layer*: Small densely packed granule cells and small pyramidal cells.

3. *Outer pyramidal cell layer* : Contains medium sized and large pyramidal cells. Apical dendrites pass to superficial layers, axons enter the white matter. ,

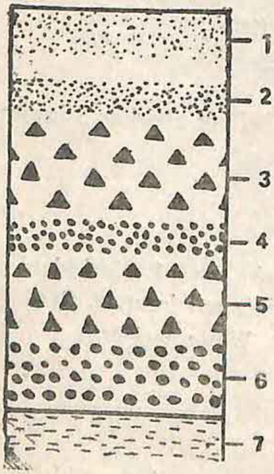


Fig. 31. Section of Cerebral Cortex. 1. Molecular layer. 2. Outer granular layer, 3. Outer pyramidal cell layer, 4. Inner granular layer, 5. Inner pyramidal cell layer, 6. Polymorphic layer, 7. White matter.

4. *Inner granular layer* : Similar to outer granular layer. Contains the *outer band of Baillarger* (thin band of white matter).

5. *Inner pyramidal cell layer*: Similar to layer 3; also contains giant pyramidal *cells of Betz* in motor cortex, which contribute about 2-3% to pyramidal tract; contains *inner band of Baillarger* (thin band of white matter).

6. *Innermost polymorphic layer*: Contains fusiform and stellate cells of different shapes and sizes.

Types

Neocortex (Isocortex) has six layers as described above. It forms 90% of the cortex i.e., motor area, sensory area.

(a) *Granular Type of Cortex*: Granule cells increase enormously e.g., sensory area, visual area, auditory area.

(b) *Agranular Type of Cortex*: is characterized by large number of pyramidal cells e.g., motor area.

Allocortex (phylogenetically older) e.g., hippocampus, dentate gyrus, have only three layers—molecular, pyramidal cell and polymorphic layers.

Mesocortex e.g., cingulate gyrus, is midway between allocortex and neocortex.

Meninges

(1) *Duramater* is a dense fibrous sheet.

(2) *Arachnoidmater* is an avascular net-like membrane which intervene between duramater and piamater. *Arachnoid villi* arise from its outer surface, pierce the duramater and project into the venous sinuses.

(3) *Piamater*, a delicate vascular membrane, is closely adherent to the brain and spinal cord. It is invaginated into the ventricles of the brain forming *choroid plexuses*.

Vessels of CNS

Cerebral arteries are typical muscular arteries. These are functional end arteries. The grey matter is more vascular than white matter. There are no lymphatics in CNS.

Blood-Brain Barrier

The passage of many substances from the blood circulation to the extra-cellular space of CNS is restricted to a great extent. This physiological barrier is termed *blood brain barrier*.

The perivascular feet of astrocytes combine with piamater to form a *pia-glial membrane,* which surround the blood vessels as they pierce the piamater into the CNS. The space between blood vessels and pia-glial membrane is called *Virchow-Robin* or *perivascular spaces.*

The structural basis for the barrier is mainly formed by the capillary endothelium and the pia-glial membrane surrounding the perivascular spaces.

The importance of blood brain barrier lies in drug therapy in disease and in anesthesia.

Regeneration in Nervous Tissue

Regeneration is not possible in CNS because (i) Schwann cells and endoneurium are absent, and (ii) the glial tissue proliferates rapidly and fills up the space (glial scar). In peripheral nerves regeneration takes place.

7 Cardiovascular System

The cardiovascular system is a system of closed tubes of varying calibres, beginning from heart and ending in the heart. It comprises the heart, the arteries, the capillaries and the veins. In the embryo, all vessels including the heart begin as capillaries adding layers of connective tissue and muscles as they develop.

HEART

The heart has (i) Inner endocardium, (ii) Middle myocardium, (iii) Outer epicardium.

The *endocardium* consists of (i) endothelium, a single layer of squamous cells and (ii) a subendothelial layer containing elastic fibres and some smooth muscle cells.

The *valves of the heart* are folds of endocardium with a central core of dense fibroelastic tissue.

The *myocardium* is the thickest layer and consists of cardiac muscle spirally arranged.

The *epicardium* (Visceral layer of pericardium) is a serous membrane.

Cardiac "Skeleton", consists of dense collagenous fibres arranged into.

(a) 4 fibrous rings which surround the atrio-ventricular, the aortic and the pulmonary orifices.

(b) 2 fibrous trigones connecting the fibrous rings.

(c) Membranous part of interventricular septum.

ARTERIES (general features)

The arteries carry blood away from the heart to the capillaries, and consist of three coats (tunics).

1. *Tunica Intima*: thin inner coat, and consists of :

(i) *endothelial lining* comprising of a single layer of squamous cells.

(ii) *Subendothelial connective tissue* containting delicate collagen and elastic fibres.

(iii) *Internal elastic lamina* composed of condensed elastic fibres, and maintains the patency of arterial lumen.

2. *Tunica Media*: Thick middle coat composed of circularly arranged smooth muscles and elastic fibres in varying proportions. It includes *external elastic lamina*, which lies at its periphery and separates it from tunica adventitia.

3. *Tunica Adventitia*: Thin outer coat, and consists of connective tissue fibres (mostly collagen) longitudinally arranged, parallel to the long axis of the vessel. It merges gradually with the surrounding connective tissues. The adventitia restrains the expansile media and intima.

Types of Arteries: A. Elastic artery, B. Muscular artery, C. Arteriole.

A. Elastic Artery (conducting artery)

Elastic arteries expand when blood is forced from the heart during ventricular systole, and then recoil slowly during diastole. Thus it maintains a continuous forward flow of blood.

Features: Usual 3 coats: T. Intima, T. media and T. adventitia.

1. *Tunica Intima*: Endothelium is smooth with absence of small folds, the subendothelial layer is thick and contains fine collagen and elastic fibres; the internal elastic lamina is difficult to identify because it blends with similar elastic fibres of tunica media.

2. *Tunica Media*: Thickest coat forming about 4/5 of the whole wall. Elastic fibres predominate, with some smooth muscle and collagen fibres.

3. *Tunica Adventitia*: Comparatively thinner than in muscular arteries.

Examples: Large arteries situated near the heart namely aorta, brachiocephalic, subclavian, carotid arteries.

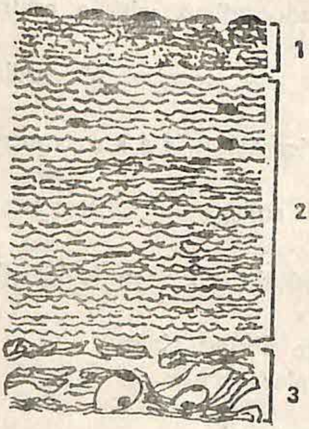


Fig. 32. T.S. of Elastic artery: 1. Tunica intima, 2. Tunica media, 3. Tunica adventitia.

B. Muscular Artery (Distributing artery)

In muscular artery blood passes at a reduced pressure and speed.

Relative to lumen, the smaller the vessel the thicker is the wall.

Features : Usual three coats : **T. Intima, T.** Media, T. Adventitia.

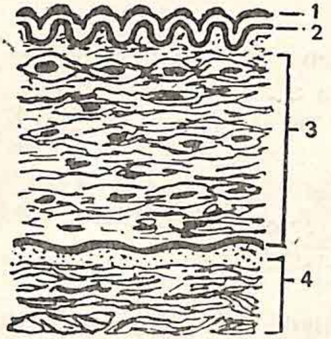


Fig. 33. T.S. of Muscular artery: 1. Endotthelium, 2. Internal elastic limina, 3. Tunica Media, 4. Tunica adventitia.

1. *Tunica Intima* : Shows numerous little folds : thin subendothelial connective tissue ; *Internal elastic lamina very prominent and thrown into small wavy folds,* due to agonal contraction of the smooth muscle of the media.

2. *Tunica Media* : Thickest of the three coats ; smooth muscle fibres predominate.

3. *Tunica Adventitia* : Thinner than tunica media, but thicker than in elastic arteries.

Examples : Medium and small arteries e.g., radial artery, femoral artery.

Arterioles

Arterioles are small muscular arteries about 100 μ ; the wall is thicker relative to the lumen. They control the flow of blood to the capillary bed by their contraction and relaxation which is regulated by vasomotor (sympathetic) nerves. By contraction they increase peripheral resistance, and therefore arterial blood pressure is raised. When they relax, more blood enters the capillaries and blood pressure falls.

Features : Larger arterioles have usual 3 coats.

1. *Tunica Intima* : Internal elastic lamina very prominent and thrown into wavy folds.

2. *Tunica Media* : Elastic fibres disappear ; only smooth muscles circularly arranged.

3. *Tunica Adventitia*: Thin fibro-elastic coat.

As the arterioles diminish in size, the internal elastic lamina becomes thinner and ultimately disappears. The muscle coat is diminished and the adventitial coat is lost. The terminal part of the arteriole is often termed terminal arteriole (precapillary) which contains a few smooth muscle cells in its wall. An arteriole loses muscle cells and usually terminates in a plexus of capillaries.

Nerve Supply of Arteries: Non-myelinated sympathetic fibres supply the smooth muscles of arteries. Myelinated sensory fibres carry pain impulses.

Capillaries

1. Capillaries are microscopic vessels with diameters of about 8μ. They branch and anastomose to form a network.
2. The wall is one cell thick ; the lining endothelial cells and their nuclei are elongated in the long axis of the vessel.
3. There is no break in the endothelial lining.
4. They are surrounded by a thin layer of connective tissue, and are accompanied by crescentic shaped mesenchymal cells termed *pericytes*.
5. Capillaries are mostly connecting links between arterioles and venules.
6. The blood flow is uninterrupted.

The capillary wall acts as a semi-permeable membrane, where exchange of substances take place.

Types (as seen in EM)

(a) *Musucular or continuous capillaries*: With uniform wall ; present in muscles.

(b) *Fenestrated capillaries*: With little proes, some of them closed by a diaphragm ; found in endocrine glands, glomerulus of kidney.

Sinusoids

1. Sinusoids are dilated vascular channels often 30μ or more.
2. They are lined by endothelium and reticulo-endothelial cells (fixed macrophages).
3. The lining is incomplete in places with gaps between the cells ; thus blood comes in direct contact with tissue cells.
4. The wall of sinusoid has only a network of reticular fibres.
5. A sinusoid may connect an arteriole with a venule (spleen, bone marrow), or a venule with a venule (liver).
6. The blood flow is sluggish.

Sinusoids permit considerable exchange of metabolites across their walls.

Types and distribution:

A. *Discontinuous sinusoids* (as described above) found in liver and spleen.

B. *Fenestrated sinusoids* (sinusoidal capillaries) are in reality wide-bored fenestrated capillaries, present in pituitary and adrenal glands.

Veins

Veins are more numerous than arteries and are usually collapsed after death. In their journey from periphery to heart, they gradually increase in calibre and their wall become thicker. In general, the wall of a vein is thinner but its lumen much larger than that of the accompanying artery. In the smallest venule, the first addition to the endothelium is collagen fibres.

Features of medium sized vein

Veins possess usual three coats : T. intima, T. media, T. adventitia.

1. *Tunica Adventitia* : Thickest of the three coats and contain mostly longitudinally arranged collagen fibres, some smooth muscle fibres and a few elastic fibres.

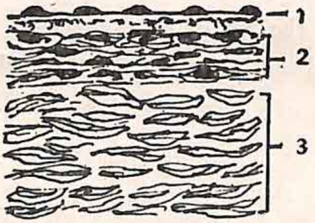


Fig. 34. T.S. of Vein, 1. T. Intima, 2. T. Media, 3. T. Adventitia.

2. *Tunica Media* : Thin, and contains mainly collagen fibres, a few elastic fibres and smooth muscle cells. The veins of central nervous system and those of bone marrow lack smooth muscle. The pulmonary veins, deep veins of penis and uterine veins during pregnancy contain a conspicuous layer of smooth muscle in their T. Media.

3. *Tunica Intima* : Thin ; internal elastic lamina absent.

Valves of the vein are mainly present in the veins of the limbs, and are *folds of tunica intima.*

Vasa Vasorum

These are small nutrient vessels which supply and drain the adventitia and outer part of media of large and medium sized blood vessels. Nutrition to the remainder of tunica media and intima is by diffusion from the blood.

Arterio-Venous Anastomosis

A.V. anastomoses are devices for short circuiting of blood from arterioles to venules. They regulate blood flow specially in organs with intermittent metabolism.

An arteriole and a venule are directly connected by a thick-walled channel which bypasses the capillary bed. The muscular wall of these anastomotic cross connections are remarkably thick and are richly supplied with vasomotor nerves that regulate the lumen. When the organ is active, the shunt (A.V. anastomosis) is closed and blood passes through the capillary bed. But when the shunt is open (relaxed) blood makes a short circuit, enters directly into the venule, and very little blood flows into the capillary bed.

Chief distribution : In gastrointestinal tract; in skin to regulate temperature.

Glomus is a specialized type of A.V. anastomosis. The anastomotic cross connection are very tortuous and have thick walls, which contain epitheloid cells (modified muscle), whose contraction occludes the narrow lumen. It regulates blood flow specially with respect to temperature regulation.

Chief distribution : nail bed, digital pads, ears.

Coccygeal Body : Situated in front of the tip of the coccyx, is a specialized type of A.V. anastomosis, whose smooth muscle cells have become epitheloid cells.

8 Lymphatic System

The lymphatic system comprises of *lymph vessels and lymphoid tissues.*

Lymph Vessels

Lymph is excess of tissue fluid. Lymph vessels return lymph from tissue spaces to the veins at the root of the neck.

(a) *Lymph capillaries* are lined by a single layer of endothelial cells.

(b) *Larger lymph vessels* have three coats resembling a venule. These vessels encounter lymph node in their path.

(c) *Lacteals* : Lymph vessels in the villi of small intestine are called lacteals. They contain milky white fluid (chyle) due to collection of droplets of emulsified fat during digestion of a fatty meal.

(d) The *thoracic duct* resembles a vein of equal size but has more muscle in the media than do comparable veins.

Lymph vessels are absent from central nervous system, splenic pulp, and avascular structures like epidermis and most cartilages.

Lymphoid Tissues

Lymphoid tissues are collections of lymphocytes in different stages of development and maturation, and are held in a framework of reticular tissue. They occur in two different forms :—

A. Diffuse Lymphoid Tissues : Present diffusely beneath the epithelium of digestive and respiratory tracts.

B. Lymph Nodules (Lymph Follicles) are small rounded masses of lymphoid tissue. They are of two types :—

(a) *Primary lymph nodule* is without a germinal centre and contains densely packed lymphocytes.

(b) *Lymph nodule with germinal centre* has two zones :—

(i) *Central zone* (germinal centre), also called secondary lymph nodule, contains loosely packed lymphoblasts and large lymphocytes, and as such takes a light basic stain.

(ii) *Peripheral zone* contains densely packed small lymphocytes, often concentrically arranged. This zone stains deep blue.

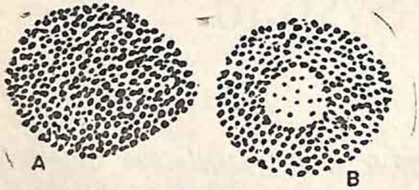


Fig. 35. Lymph nolules : A. without germinal centre, B. With germinal centre.

Distribution : Numerous lymph nodules with or without germinal centre are found embedded in diffuse lymphoid tissue. Aggregated nodules are present in ileum where they are called Peyer's patches. Lymph nodules are also present in lymph node, spleen and tonsil.

Lymphoid Organs

Organised collections of lymphoid tissue are called lymphoid organs. The main lymphoid organs are lymph node, spleen, thymus and tonsils.

LYMPH NODE

Lymph nodes are bean shaped encapsulated masses of lymphoid tissue lying in the path of lymph vessels.

Features

A. *Connective tissue framework* consisting of (i) dense capsule comprising mainly of collagen fibres and a few smooth muscle cells, (ii) trabeculae and (iii) reticular connective tissue forms fine framework.

B. *Subcapsular lymph sinus* is a loosely meshed area under the capsule. Similar areas termed *trabecular sinuses* are present along the trabeculae. In the lymph sinuses lymphocytes are few in number and the reticular stroma becomes apparent. Lymph sinuses filter lymph.

C. Lymph node is divisible into an outer *cortex*, and an inner *medulla* near the hilus.

(i) Outer cortex is densely packed and contains a variable number of lymph nodules, *many having germinal centres*. The cortical nodules are *Bursa dependant part* and are responsible for serum mediated immune responses.

(ii) Inner medulla contains irregular branching and anastomosing cords of lymphocytes. The deeper para-cortical lymphoid tissue is *thymus dependant* and are concerned with cell mediated immune responses.

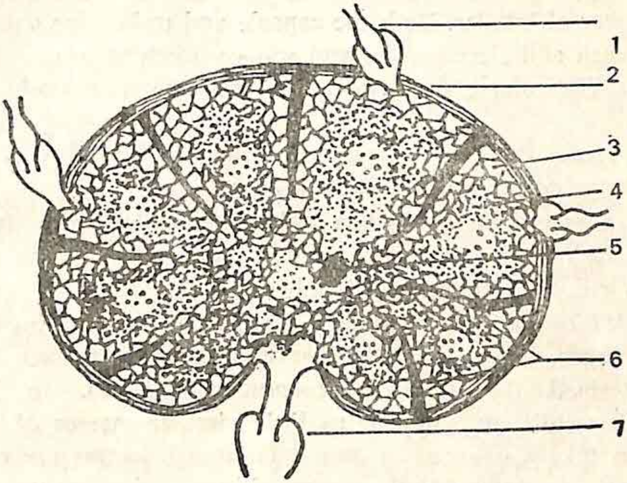


Fig. 36. Section of Lymph node: 1. Afferent lymphatic. 2. Capsule, 3. Sub-capsular sinus, 4. Cortex showing lymph nodules, 5. Medulla, 6. Septa, 7. Efferent lymphatic.

Lymph circulation

Lymph enters the subcapsular lymph sinus from afferent lymph vessels which enter the node on its convex surface. It then passes through the trabecular sinus and leaves the lymph node at the hilus via the efferent lymph vessels. **Valves in the vessels control the flow.**

Functions of lymph nodes

1. Produce lymphocytes and antibodies.
2. Phagocytosis by macrophages and thereby lymph is purified.
3. Acts as filter of lymph.

SPLEEN

Spleen is the largest lymphoid organ and is placed in the path of a blood vessel. It is often termed a haemolymph node.

Features

A. *Connective tissue framework :*

(i) Thick capsule covered by visceral peritoneum (mesothelium).

(ii) Prominent trabeculae extend inwards from the capsule and Rilum. They branch and anastomose and thus divide the spleen into large number of lobules. Both the capsule and trabeculae consist mainly of collagen and elastic fibres and some smooth muscles.

(iii) Reticular connective tissue forms the framework of splenic pulp.

B. *Splenic Pulp* (Substance of spleen): *Spleen is not differentiated into cortex and medulla.*

Types: Red pulp and white pulp —So called from its appearance in fresh section, in which white specks (white pulp) are scattered in a red background (Red pulp).

(a) *White pulp* are masses of lymphoid tissue surrounding the follicular arteries like a sheath. At intervals they thicken into oval masses, termed the *Malpighian corpuscles (follicles)*. In histologic sections the while pulp appear as little circular masses of lymphoid tissue that take a deep basic stain. Germinal centres are present in some follicles. Although the artery occupies an eccentric position within the follicle, it is called *central artery of the white pulp*.

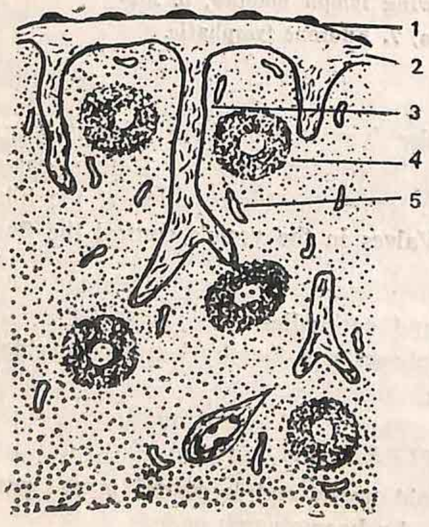


Fig. 37. Section of spleen: 1. Mesothelium, 2. Capsule, 3. Trabeculae, 5. White pulp with central arteriole, 5. Sinusoids in red pulp.

(b) *Red pulp* is a modified lymphoid tissue of the diffuse type, and consists of venous sinusoids and the spongy network of splenic cords (Billroth's cords) between them.

The splenic cords contain usual elements of lymphoid tissue together with circulating elements of blood cells.

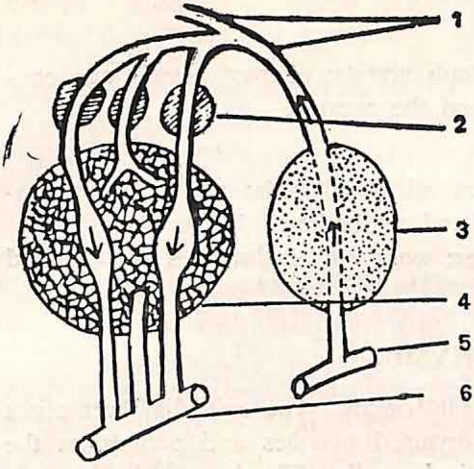


Fig. 38. Splenic blood circulation: 1. Penicilli, 2. Ellipsoid, 3. White pulp with central arteriole, 4. Sinusoids in red pulp, 5. Trabecular artery, 6. Trabecular vein.

Splenic Circulation

The branches of splenic artery enter the hilus and run along the trabeculae. Small arteries leave the trabeculae to enter the white pulp, where the fibrous adventitia is replaced by lymphoid tissue. As mentioned above the arteries are placed eccentrically in the follicles (white plup). The arteries then enter the surrounding red pulp and divide into a number of straight vessels termed *penicilli*. The penicilli have three parts. The first part is the *pulp artery*. The second part is the *ellipsoid* (Schweigger Seidel Sheath) in which the media is lost and there is accumulation of reticular cells surrounding the endothelial lining; thus there is spindle shaped thickening of its wall and the lumen is narrowed. The third part is an arterial *capillary*, the termination of which is not clear. There are three main theories :

(i) According to *'open circulation' theory* the capillaries open directly into the splenic cords of the red pulp, from where blood gradually filters into the venous sinusoids.

(ii) According to *'closed circulation' theory* the capillaries are directly continuous with the venous sinusoids.

(iii) The *'Compromise' view* holds: When the spleen is distended, the lining cells of the sinusoids move apart and permit blood to enter the splenic cords of red pulp, but when the spleen in contracted the lining cells come together, and the circulation becomes functionally closed.

The sinusoids empty into the pulp veins, which unite to form trabecular veins, which in turn form splenic vein.

Lymphatics

Spleen has no afferent lymph vessels; efferent vessels are confined to the major trabeculae and the capsule.

Functions :

1. Foetal spleen produces all blood cells; adult Spleen produces monocytes, lymphocytes and antibodies.
2. It acts as a blood filter; worn out erythrocytes are engulfed and ingested by macrophages.

THYMUS

Thymus is a lympho-epithelial organ. The epithelial part arises from the entoderm of 3rd pharyngeal pouches and persists as the *Hassall's corpuscles* and the ***reticular cells***. The lymphoid tissue is of mesodermal origin. Afferent lymph vessels, lymph sinuses or germinal centres are absent in the thymus.

Features

A. *Connective tissue framework* comprising (i) Thin capsule; septa of collagen and elastic fibres divide the two lobes into numerous lobules, (ii) The fine stroma is formed by *epithelial reticular cells* (entodermal). They are not connective tissue elements and are not phagocytic, and as such not a part of reticulo-endothelial system.

B. Parenchyma :

Each lobule has two parts (a) Peripheral cortex and (b) central medulla. In reality the lobules are not separate, as the medulla forms the central core of each lobe and extends into each lobule. As such in each lobule the cortex is absent on the deep side. But sections near the surface give the appearance of separate lobules and it seems as if the medulla is completely surrounded by cortex.

(a) Thymic cortex consists of densely packed lymphocytes (thymocytes) and takes a deep basic stain. There are no circumscribed germinal centres but mitosis occurs everywhere in the cortex.

(b) Medulla is loose, takes a light basic stain and contains:—

(i) Small lymphocytes and a network of epithelial reticular cells besides some macrophages. These small lymphocytes of thymic medulla enter blood stream to form the pool of long lived circulating T-lymphocytes, which are responsible for cell mediated immune responses.

(ii) *Hassall's corpuscles* : These are concentrically arranged epithelial cells around a central hyaline necrotic eosinophilic mass.

Peculiarity of blood supply to thymus

Surrounding the thymic blood vessels are perivascular spaces which are bounded on the outside by the epithelial reticular cells. This forms a physiological barrier, the so called *hemothymic barrier* and prevents the thymic lymphocytes from being exposed to antigens.

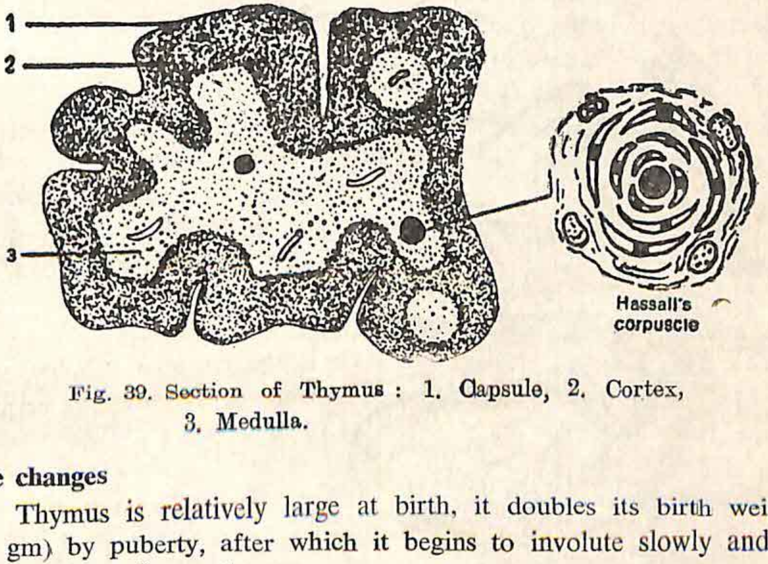


Fig. 39. Section of Thymus : 1. Capsule, 2. Cortex, 3. Medulla.

Age changes

Thymus is relatively large at birth, it doubles its birth weight (12 gm) by puberty, after which it begins to involute slowly and is replaced by adipose tissue.

Functions

Thymus produces lymphocytes and maintains the normal concentration of blood and tissue lymphocytes. Most of the thymic lymphocytes have a life span of 3 to 5 days. About 5% are thrown into circulation, these are long lived T-lymphocytes.

The thymic epithelial reticular cells probably produce *two hormones*—(a) *lymphopoietin*, which stimulates the production of lymphocytes in thymus and other lymphoid tissues and (b) *Competence inducing factor*, makes the newly formed lymphocytes immunologically competent.

Thymic resection at birth results in severe immunological crippling.

TONSILS

Tonsils include palatine, lingual (see Tongue) pharyngeal and tubal tonsils. All are locatel under an epithelial surface and are partly covered by a capsule.

A. Palatine Tonsil

Features :

1. Lateral surface covered by a capsule of connective tissue.
2. Medial surface is pitted by some 10 to 20 *tonsillar crypts;*

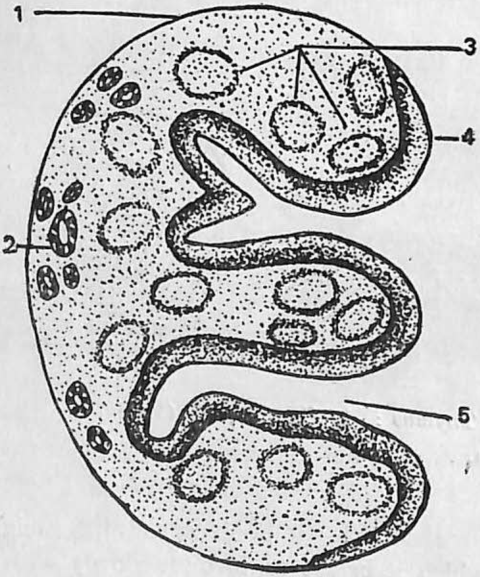


Fig. 40. Section of Palatine Tonsil: 1. Capsule, 2. Mucous glands, 3. Lymph nodules, 4. Stratified squamous epithelium (N. K.) 5. Tonsillar crypt.

both the medial surface and the crypts are lined by stratified squamous epithelium (non-keratinised).

3. Lymph nodules with germinal centres are present in diffuse lymphoid tissue under the epithelium.

4. Many mucous glands are present in the underlying connective tissue.

The epithelium of tonsil is invaded by numerous lymphocytes, some of which pass through the epithelium into the saliva and are called *salivary corpuscles.*

B. Pharyngeal Tonsil

The pharyngeal tonsil is lined by pseudo-stratified columnar ciliated epithelium. The mucous membrane shows numerous folds. Enlarged pharyngeal tonsil in children is called *adenoid.*

9 Endocrine Glands

HYPOPHYSIS CEREBRI (PITUITARY GLAND)

The hypophysis is located in the sella turcica of sphenoid bone, and is connected to the floor of third ventricle by the infundibulum.

Parts: A. Adenohypophysis, B. Neurohypophsysis.

The *Adenohypophysis* arises from the ectodermal roof of primitive mouth cavity. It has three subdivisions : *Pars distalis*, *Pars intermedia*, and *Pars tuberalis*.

The *neurohypophysis* is neuro-ectodermal in origin and arises as a downgrowth from the floor of third ventricle. It also has three subdivisions: *Median eminence* (central part of tuber cinerium). *infundibular stalk* and *infundibular process* (*pars nervosa*).

The whole gland is enclosed in a thin fibro-elastic capsule.

1. Pars Distalis

Pars distalis forms the bulk of pituitary gland. It consists of clumps or cords of epithelial cells arranged around the sinusoids and supported on a reticular framework.

Cell types : Three types of cells are described with the usual H & E staining : *Chromophobes* (50%), *Acidophils* (40%) and *Basophils* (10%). The percentages given are those in the rat. In human being there is extreme variation.

Chromophobes : Smallest cells in pars distalis; cytoplasm agranular and takes a light stain. The cells are often present in groups. Most probably the chromophobes are degranulated exhausted cells (inactive resting cells) capable of differentiating into a particular type of chromophil.

Acidophils : Contain eosinophilic granules in their cytoplasm. Subtypes of Acidophils :

1. *Somatotrophs* produce growth hormone (somatotropin : STH), which stimulates the epiphyseal plates in growing long bones.

2. *Prolactin cells* produce prolactin (lactogenic hormone: LTH), which activates secretion of milk.

Basophils: Largest cells in pars distalis; the granules are smaller than in acidophils, and take a basic stain. Subtypes of Basophils:

1. *Thyrotrophs* produce thyroid stimulating hormone (TSH).
2. *Gonadotrophs* produce follicle stimulating hormone (FSH), luteinising hormone (LH) or Interstitial cell stimulating hormone (ICSH).
3. *Corticotrophs* produce adrenocorticotrophic hormone (ACTH).

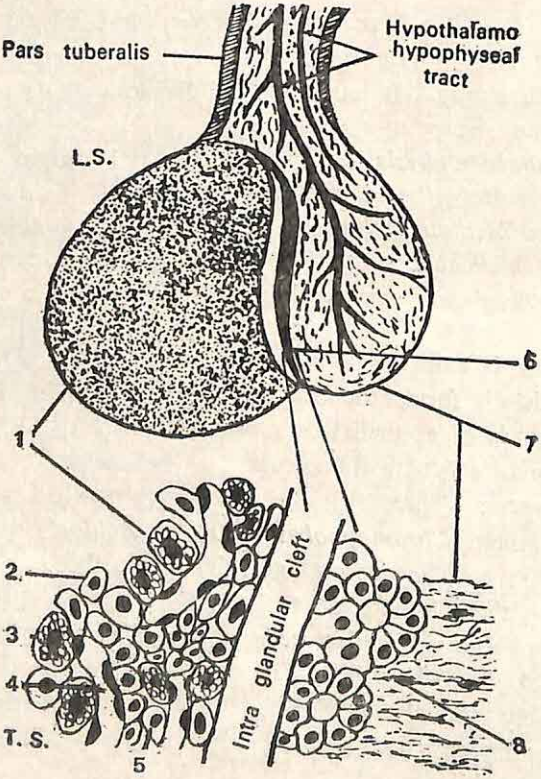


Fig. 41. Pituitary gland: 1. Pars distalis, 2. Acidophil cells, 3. Basophil cell, 4. Sinusoid, 5. Chromophobe cell, 6. Pars intermedia, 7. Pars nervosa, 8. Pituicyte.

2. Pars Intermedia

Pars intermedia is rudimentary in man. It forms a thin layer behind the residual intraglandular cleft lying in intimate contact with pars nervosa. It contains small cells with basophilic granules and secretes *melanocyte stimulating hormone* (MSH). Cysts are of common occurrence filled with colloid like material.

3. Pars Tuberalis

Pars tuberalis is the upward extension of pars distalis and surrounds infundibulum. The cells are arranged in long columns with elongated capillaries between them. Most cells are similar to chromophobe cells of pars distails. Cells are often arranged in the form of vesicles filled with a colloid like material. Function is not known.

4. Pars Nervosa

Pars nervosa is the smaller fibrous looking part. It contains *pituicytes* and large number of non-myelinated nerve fibres.

The *pituicytes* are neuroglia like cells with branching processes; their main function is supportive.

The non-myelinated nerve fibres are mainly derived from the supraoptic and paraventricular nuclei of the hypothalamus, and terminate in pars nervosa as bulbous expansions in relation to blood vessels. Two hormones ADH and oxytocin produced by these nuclei migrate along the axons in the form of membrane bound granules and are stored in pars nervosa. These accumulations of neurosecretions are called 'Herring bodies' and are contained within the bulbous expansions of nerve terminals. Oxytocin causes contractions of smooth muscles of uterus and mammary gland; ADH conserves water by acting upon the distal convoluted tubules and the collecting tubules. Damage to the tract or posterior lobe causes *diabetes insipidus*.

Blood Supply

The hypophysis is supplied by a pair of inferior hypophyseal and a pair of superior hypophyseal arteries. The inferior hypophyseal arteries supply the lower part of infundibular stalk and the pars nervosa. The superior hypophyseal arteries supply the upper part of infundibular stalk and the median eminence, where they break up into capillaries. These capillaries reunite to form longitudinal vessels which pass down through the pars tuberalis and supply the pars distalis. This is termed *Hypophyseal Portal System* and forms an important functional link between the hypothalamus and pars distalis. Thus hypothalamus controls the secretions of adenohypophysis.

THYROID GLAND

The thyroid gland is situated in the front of the neck and consists of two lateral lobes connected by an isthmus. It is entodermal in origin.

Connective Tissue Framework

1. *Capsule* consisting of (a) outer *false capsule* derived from pretracheal fascia and (b) Inner *true capsule* (condensation of peripheral stroma).

2. *Septa* pass inside from the true capsule and divide the lobes and isthmus into lobules, each of which contains a large number of follicles, closely knit together by *reticular connective tissue* (inter-follicular tissue) containing numerous blood vessels, lymphatics and nerves.

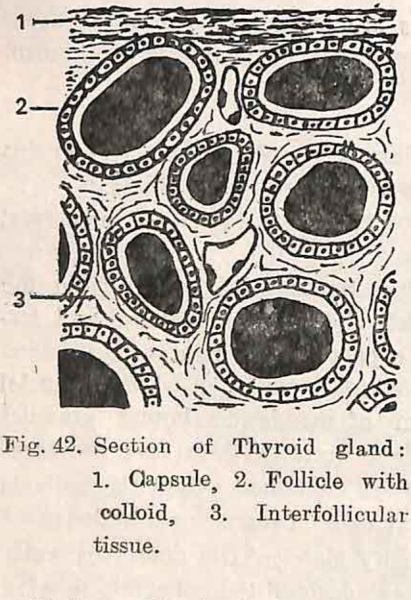


Fig. 42. Section of Thyroid gland: 1. Capsule, 2. Follicle with colloid, 3. Interfollicular tissue.

Thyroid follicles

The thyroid follicles are of various shapes and sizes; in section they appear round or oval. The *wall* of each follicle is formed by simple cuboidal epithelium. The luminal ends of these cells are covered with microvilli. The *lumen* of the follicles contain a homogeneous colloid (iodothyroglobulin) which takes an eosinophilic stain. The colloid is thyroglobulin rich in iodine.

Both the follicular epithelium and the colloid content show changes in different functional conditions: (a) when the follicles are *active*, the cells become columnar and the colloid decrease in quantity, (b) when *resting*, the cells become low cuboidal with much stored colloid in the lumen.

Para Follicular Cells (C cells)

These are large cells located both in the follicular epithelium and in the interfollicular tissue, and have a high concentration of α glycerophosphate dehydrogenase. They produce *thyrocalcitonin*, which lowers serum calcium level.

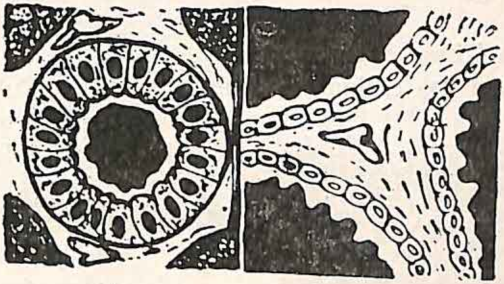


Fig. 43. Phasic changes in thyroid follicles: A. Active, B. Inactive.

Blood Vessels, Lymphatics & Nerves

The thyroid gland is very vascular ; rich capillary network (fenestrated type) surround each follicle, but *there are no sinusoids*. It has also extensive lymphatic network, which carries part of thyroid secretion. Post-ganglionic sympathetic fibres supply the blood vessels.

Cyto-Physiology of Follicular Cells

The thyroid gland manufactures hormones (thyroxine and tri-iodothyronine) from materials available in blood, stores it for the future, and releases it when needed.

Thyroid follicular cells are two-way traffic in the formation and release of its hormones. The various stages are :

Selective uptake of iodide by the follicular cells (*Iodide trapping*). In the follicular cell nascent iodine is liberated by iodide peroxidase. Formation of *thyroglobulin* from aminoacids including *tyrosine* and carbohydrate grpup—Passage of both iodine and thyroglobulin inside the follicular lumen—Iodination of tyrosine moiety of the thyroglobulin (i.e., MIT. DIT. T3 and T4) forming iodothyroglobulin inside the follicles and storage there—Uptake of iodothyroglobulin by the follicular cells where they are broken down liberating thyroid hormones, which pass from the basal surface of the follicular cells to blood and lymph.

Function

The thyroid hormones regulate the rate of metabolism throughout the body, and is necessary for normal growth and maturation.

PARATHYROID GLAND

Two pairs of parathyroid glands (superior and inferior) are located within the false capsule of the thyroid gland. They are of entodermal origin.

A. Connective Tissue Framework

Each gland has a thin fibro-ealstic capsule. Delicate septa extend inwards and merge with the reticular framework.

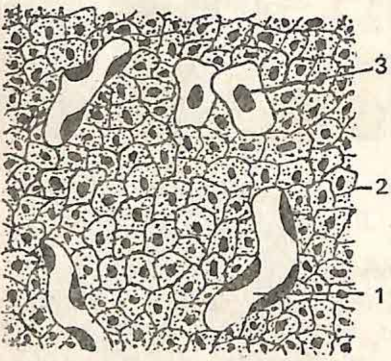


Fig. 44. Section of parathyroid gland: 1. Sinusoid, 2. Chief cell, 3. Oxyphil cell.

B. Parenchyma

The parenchyma consists of cords of epithelial cells arranged around the sinusoids. The cells are of two types:

1. *Chief (Principal) cells* have clear cytoplasm and vesicular nucleus. They secrete *parathormone* which maintains calcium and phosphate metabolism.

Two subtypes as recognised by EM.

(a) *Active Principal cells*—rich in granular endoplasmic reticulum and Golgi complex.

(b) *Inactive Principal cells*—rich in glycogen.

2. *Oxyphil cells*—Large cells with acidophilic granules in their cytoplasm. Function not known.

SUPRARENAL GLANDS

The suprarenals are paired glands located at the upper pole of each kidney. Each gland has two parts: an outer *cortex* and an inner *medulla* which differ in origin, structure and function. Medulla comprises about 10% of the whole organ.

A. Connective Tissue Framework

The gland is enclosed in a thick fibroelastic *capsule* containing few smooth muscle cells. Thin *septa* pass inside for varying depth into the cortex and become continuous with the reticular connective tissue.

B. Cortex

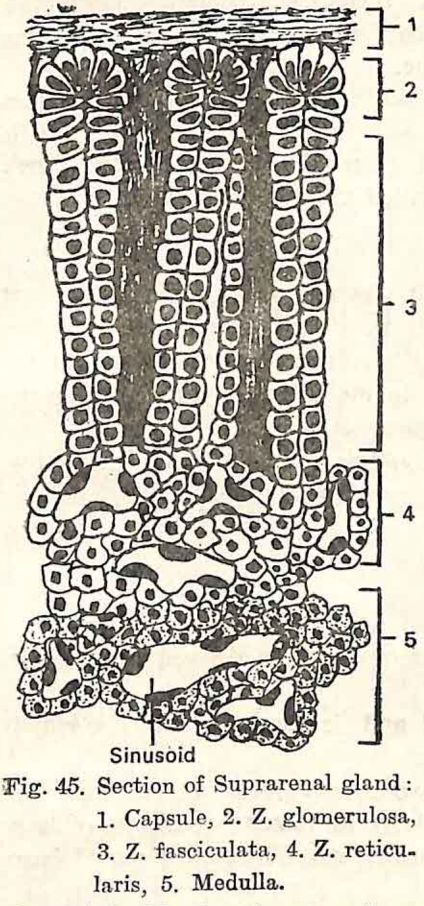


Fig. 45. Section of Suprarenal gland: 1. Capsule, 2. Z. glomerulosa, 3. Z. fasciculata, 4. Z. reticularis, 5. Medulla.

The cortex is divided into *three zones*, on the basis of patterns of cell arrangement.

1. *Outer zona glomerulosa* : Thin layer located beneath the capsule. It consists of short columnar cells arranged in rounded groups. The cells have light basophilic cytoplasm and prominent nuclei. It secretes mineralocorticoids (aldosterone and deoxycorticosterone) which maintain the water and electrolyte balance.

2. *Middle zona fasciculata* : Thickest zone consisting of cords of polyhedral cells arranged in parallel rows. The cells have basophilic cytoplasm with many lipid droplets and appear vacuolated in sections as the lipids are washed out. The nuclei are vesicular. Between the columns of cells lie connective tissue septa and bood capillaries. This zone is rich in vitamin C and cholesterol, and secretes glucocorticoids (cortisone and cortisol) which maintain carboydrate, protein and fat metabolism. This zone also produces a little amount of sex-hormones.

3. *Inner zona reticularis* : Consists of cords of polyhedral cells arranged in anastomosing networks around the sinusoids. There are two types of cells, some *light staining* and others *dark staining*. Dark staining cells are present in the innermost part; they are old cells undergoing degeneration. This zone produces some sex hormones.

C. Medulla

Medulla consists of cords of deep basic staining cells arranged in anastomosing network around wide sinusoids. The cells are of two types—adrenaline and nor-adrenaline secreting cells. These cells contain variable number of specific secretory granules (chromaffin granules) in their cytoplasm. The suprarenal medulla secretes adrenaline and a little nor-adrenaline.

Chromaffin reaction: Potassium dichromate solution colours suprarenal medulla yellow brown. This is chromaffin reaction and is due to oxidation of catechol amines (adrenaline and nor-adrenaline). Cells responding in this way are called chromaffin cells.

Blood Vessels & Nerves

The suprarenal gland has a rich vascular supply. The inner part of the capsule contains a rich capillary plexus from which branches pass in the thin septa between the cells columns: some empty into the sinusoids of zona reticularis, some in medullary sinusoids and some branches pass directly to the medullary cells.

Myelinated preganglionic fibres supply the cells of the suprarenal medulla. The cells of medulla represent sympathetic post-ganglionic neurons.

Histogenesis

The suprarenal gland is derived from two enbryonic sources :

A. *Suprarenal medulla is ectodermal* and is derived from neural crest.

B. *The cortex is mesodermal* and is derived from coelomic epithelium.

In foetal life the cortex has two zones : *foetal cortex* and *true cortex*. The foetal cortex forms a large inner zone consisting of large acidophilic cells; the true cortex consists of a thin outer layer of basophilic cells.

Foetal cortex begins to degenerate (involute) during the last two months of foetal life and disappears entirely by the end of 1st year. The adult cortex is slowly formed by proliferation and differentiation of the outer true cortex. By the end of 3rd year the zones are well formed.

Age changes in suprarenal glands : At 8th week of foetal life—Equal to kidney ; at birth—1/3 of kidney ; in the adult—1/30 of kidney.

Paraganglia

Paraganglia are small masses of chromaffin cells along the course of sympathetic trunk, the largest being *para-aortic bodies* which lie at the bifurcation of abdominal aorta. They contain epitheloid cells which are arranged in relation to many blood vessels. These cells resemble those of the suprarenal medulla and have a similar origin.

PINEAL BODY (EPIPHYSIS)

The pineal body is a small conical organ attached by a short stalk to the roof of 3rd ventricle.

A. Cell types: (1) Pineal (chief) cells: Have long branched processes with bulbous ending, (2) Atypical glial cells resembling astrocytes.

B. Brain sand (Acervulus): Small concretions of mineral salts (phosphates and carbonates of calcium and magnesium) which increase in number and size with age. They are laminated and often lobulated.

The pineal body contains *melatonin*, whose function is not known.

10 The Integumentary System

The integumentary system comprises the skin, hairs, nails and cutaneous glands including the breast.

THE SKIN

The skin covers the surface of the body and is continuous with the moist mucous membranes at the various mucocutaneous junctions. It contains sensory end organs (receptors) for pain, temperature and touch sensations.

Parts and features

A. Outer *epidermis* derived from ectoderm.
B. Inner *dermis* derived from mesoderm.

A. Epidermis

The *Epidermis* consists of stratified squamous epithelium keratinised and has 5 layers :

(i) *Stratum basale* : A single layer of deeply basic large columnar cells in contact with dermis.

(i) *Stratum spinosum* : Several layers of polyhedral cells joined to one another by fine protoplasmic bridges. Mitosis occurs in both the above layers and as such the two layers together are called *stratum germinativum*.

(iii) *Stratum granulosum* : One to five layers of somewhat flattened polyhedral cells. These cells contain *keratohyalin* granules and stain deeply.

(iv) *Stratum lucidum* : Homogeneous layer of clear flat cells. The cells are closely packed and the nuclei are not apparent. The cells are dying or already dead and contain droplets of *eleidin*.

(v) *Stratum corneum* : Most superficial; consists of several layers of flattened cornified plates of dead cells. The cells are converted into horny material called keratin (scleroprotein). The most superficial cells are continuously lost and are replaced by cells that arise from mitotic activity in stratum germinativum.

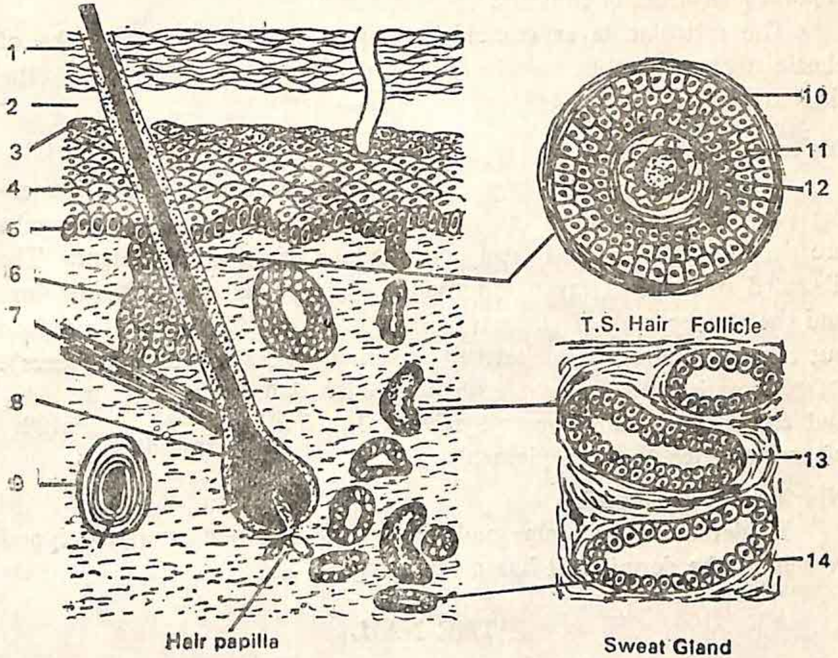


Fig. 46. Vertical section of skin: 1. Str. corneum, 2. Str. lucidum, 3. Str. granulosum, 4. Str. spinosum, 5. Str. basale, 6. Sebaceous gland, 7. Erector pilorum, 8. Hair bulb, 9. Pacinian corpuscle, 10. Dermal sheath, 11. Epidermal sheath, 12. Hair root, 13. Duct of sweat gland, 14. Secretory tubule of sweat gland.

Regional differences

The epidermis of palm and sole are thick and have all the 5 layers. On general body surface it is thin and always contains stratum basale, stratum spinosum and a thin stratum corneum ; stratum granulosum is poorly developed or absent, and stratum lucidum is also lacking.

B. Dermis (Corium)

Dermis is a connectve tissue layer containing blood vessels, lymphatics and nerves of the skin. It also contains hair follicles, sweat and sebaceous glands (all ectodermally derived structures).

Parts: Outer *papillary layer*; inner *reticular layer*.

The papillary layer contains large number of papillae (*dermal papillae*) protruding into the epidermis.

The reticular layer contains collagen bundles and networks of elastic fibres. Smooth muscles (erector pilorum) are present in relation to hair follicles.

Melanocytes

The Melanocytes are pigment producing cells with highly branching processes situated at the dermo epidermal junction. These cells are derived from neural crest and produce melanin pigment. The liberated melanin is taken up by the cells of stratum germinativum and the deeper part of stratum spinosum. Cells that do not produce but take up melanin are termed *chromatophores* (melanophores). DOPA test is used to distinguish between melanocytes (Dopa positive) and chromatophores (Dopa negative). In *albinism* there is inability of melanocytes to form pigments.

Nutrition of Epidermis

Epidermis is avascular and derives its nutrition from the blood vessels of the dermis. It has no lymphatics.

THE NAIL

The nail is a modified epidermis and develops from stratum lucidum.

Parts: 1. Root (proximal part) covered by skin and 2. Body is visible part.

The body of nail is pink due to underlying vascular bed except a whitish area (*lunule*) near the root.

The nail is supported and attached to the *nail bed* which consists of stratum germinativum and dermis. The part of nail bed supporting the root of nail is called *nail matrix*, from which new formation of nail takes place.

HAIR

Hair is a flexible horny thread composed of cornified cells and develops from epidermis.

Parts: 1. *Shaft*, 2. *Root*.

The *shaft* projects above the skin. The *root* is embedded within the skin in a tubular space termed the *hair follicle*. The deep end of the root expands into the *hair bulb*, which is moulded over vascular connective tissue called *hair papilla.* Sebaceous glands and erector pilorum (smooth muscle derived from ectoderm) are associated with hair follicle. The erector pilorum is innervated by sympathetic nerves ; its reflex contraction causes erection of hairs.

Structure of the hair

The hair consists of medulla, cortex and cuticle (from within outwards).

(a) *Medulla* consists of keratinised cuboidal cells with air spaces between them.

(b) *Cortex* forms the main bulk of hair and contains spindle-shaped cells united to form fusiform fibres.

(c) *Cuticle* : A single layer of flat scales which overlap one another from below upwards.

Structure of hair follicle

The hair follicle consists of:

(1) *Epidermal root sheath* closely adherent to the root of the hair and consists of inner and outer root sheaths.

(2) *Connective tissue (dermal) sheath* formed by the vascular fibrous tissue of the dermis, surrounding the epidermal root sheath.

Sweat Glands

Sweat glands are simple coiled tubular glands of merocrine (eccrine) type. Besides excretion these glands help in temperature regulation by sweating.

Secreting tubules lie deep in the dermis lined by a single layer of cuboidal cells. Myo-epithelial cells are present between the secreting cells and the basal lamina.

Ducts are lined by two layers of dark staining cuboidal cells.

Distribution: Throughout the skin, except margin of lips, nail bed, prepuce and glans peins.

Specialized sweat glands :

1. *Apocrine sweat glands* are large and branched tubular glands present in axilla, circumanal region, scortum and labia majora.

2. *Ceruminous glands* in the external auditory meatus: The lumen of the glands are large and the secretion is thick.

3. *Ciliary glands* in the eyelids.

Sebaceous Glands

Sebaceous glands are branched alveolar glands of the *holocrine* type in which secretion occurs by fatty disintegration of the entire cell.

Secreting alveoli: The alveoli consist of stratified epithelium which nearly fill the whole alveoli. Basal cells proliferate and the superficial cells are pushed into the centre of the gland, where they die, disintegrate and become sebum.

Duct: Very short and lined by stratified epithelium and opens into the neck of a hair follicle.

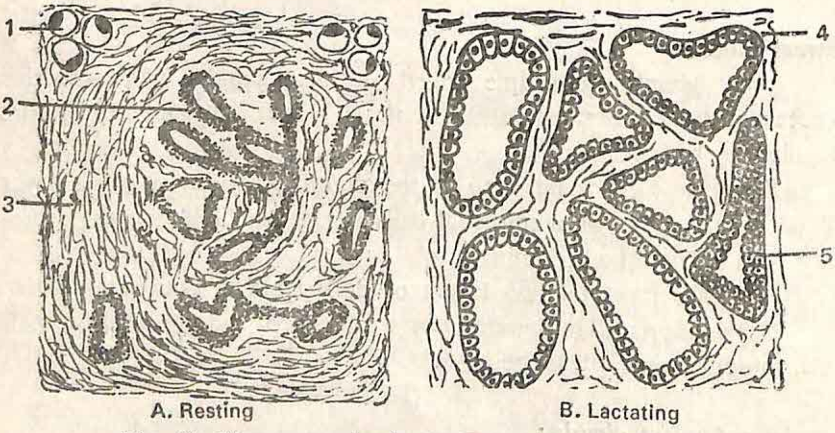
Distribution: Mostly associated with hair follicles; some are independent of hair follicle e.g., at the lip margins, glans penis, inner surface of prepuce, labia minora, and tarsal glands of eyelids. Sebaceous glands are absent from palms and soles.

Nerve Supply of Skin

Efferent nerves supply erector pili, cells of sweat glands and smooth muscles of blood vessels; sensory nerve fibres form free nerve endings in dermis and epidermis, and end in encapsulated end-organs.

MAMMAR GLAND

The paired mammary glands are present in both sexes. In male they are rudimentary throughout life. In female they are small before puberty but develop considerably at and after puberty, attain a maxi-



A. Resting B. Lactating

Fig. 47. Mammary gland: 1. Fat cells, 2. Shrunken alveoli, 3. Connective tissue, 4. Alveolus, 5. Interlobular duct.

mum during pregnancy, become functional after child birth and atrophy in old age.

The mammary gland is modified sweat gland of the apocrine type and is classified as compound tubulo-alveolar gland. It is ectodermal in origin.

The *areola* and *nipple* have thin pigmented skin devoid of hair ; the dermis contains smooth muscles oriented circularly and radially. Besides, the areola contains modified sweat glands termed *areolar glands* (of Montgomery).

Lobes, Lobules, Alveoli and Duct system :

Each gland is composed of 15 to 20 *lobes* separated by dense fibro-fatty tissue. Dense connective tissue divides the lobes into *lobules.* Each lobule contains numerous *alveoli* embedded in loose vascular connective tissue, which provides a nutritive and expansile bed for future functional alveoli. Actually each lobe is an independent unit with its own duct system. The alveoli open into small *intralobular ducts,* which unite to form *interlobular ducts*, and these in turn form the *lactiferous ducts* (15-20). The lactiferous ducts, one from each lobe converge towards the nipple. Beneath the areola each duct is locally dilated to form *lactiferous sinus* and finally opens on the summit of the nipple. The *lactating* and *non-lactating resting* glands differ markedly in histological appearance.

Lactating Gland

During lactation, the lobules are packed with alveoli and the interlobular stroma is deduced to thin septa. The alveoli are large, of irregular outline, and are lined by *single layer of cuboidal to columnar cells.* Myoepithelial cells, located between the lining cells and the basal lamina help in the ejection of milk. Many alveoli are dilated by milk and have thin walls.

The ducts leading from the alveoli are much like alveoli in structure and function. The remaining duct system is lined by two layers of cuboidal cells. The lactiferous ducts near the nipple have stratified squamous epithelium.

Non-Lactating Resting Gland

The resting gland shows clusters of ducts separated by abundant connective tissue. The alveoli shrink and the lumen may be lost ; they are represented around the terminal portions of the ducts as very small follicles (lined by simple cuboidal epithelium) and a few solid cords of epithelial cells. The ducts are lined by two layers of cuboidal cells.

Age Changes in Mammary gland:

1. *During Foetal life* cords of epithelial cells from *milk line* invade the underlying connective tissue and later become canalized.
2. *At birth* a rudimentary duct system is present in a fibrous stroma.
3. *Till puberty* the breast grows by deposition of fibro-fatty tissue ; only the ducts slightly branch.
4. *At puberty*: Increase of duct system induced by oestrogen. The ends of ducts form solid spherical masses (potential alveoli). Secretory units do not develop until pregnancy. At the same time accumulation of fat swells the breast.
5. *During pregnancy* :

(a) *In the 1st half* there is marked branching of ducts. True secretory alveoli develop from the terminal parts of the ducts. By 5th month lobules are packed with alveoli—as a result of combined oestrogen and progesterone action.

(b) *In the 2nd half* the alveoli enlarge, and elaborate secretion precursors. At the end of pregnancy *colostrum* is produced.

During pregnancy the areola and nipple become darker, and areolar glands enlarge to form tubercles.

6. *During lactation* : Already described.
7. *After lactation*: The gland returns to resting condition, as already described.
8. *After Menopause* : The gland involutes i.e., undergoes regressive changes. The parenchyma decreases or disappears and is replaced by varying amount of fibro-fatty tissue.

11 Respiratory System

The respiratory system comprises of the nasal cavity, the pharynx, the larynx, the trachea, bronchi and the lungs.

Nasal Cavities

The paired nasal cavities are supported by cartilages and bones, and lined by mucous membrane.

Parts : Vestibule, respiratory region, olfactory region.

Vestibule is lined by stratified squamous epithelium and contains numerous coarse hairs (vibrissae), sebaceous and sweat glands.

Respiratory region is lined by pseudostratified columnar ciliated epithelium with many goblet cells. The subepithelial connective tissue is very vascular, which serves to warm the inspired air. Mixed serous and mucous glands are also present.

Olfactory region is lined by a neuroepithelium which contains three types of cells : *olfactory*, *supporting* and *basal*. The olfactory cells are bipolar neurons, the free end serves as a dendrite and is provided with 6 to 12 olfactory hairs. The central processes form a plexus in the mucous membrane, from which about 20 bundles of fibres arise, pierce the cribriform plate and end in the olfactory bulb. The supporting cells are tall columnar, while the basal cells are small cuboidal cells lying between the bases of other cells. The lamina propria contains small tubuloalveolar olfactory glands.

Paranasal Sinuses are lined by pseudostratified columnar ciliated epithelium.

Pharynx (See Digestive system).

Larynx

The larynx is supported by cartilages, moved by muscles and lined by mucous membrane.

Mucous membrane

The larynx is mostly lined by pseudostratified columnar cilliated epithelium *except vocal folds, aryepiglottic folds and most of epiglottis which are lined by stratified squamous epithellum non-keratinised.* The lamina propria contains small mixed sero-mucous glands.

Cartilages

Thyroid, cricoid and basal parts of arytenoid cartilages are of hyaline variety. The apical parts of arytenoid,. cuneiform, corniculate and epiglottic cartilages are of elastic variety.

EPIGLOTTIS

The epiglottis is a leaf like structure located in the anterior wall of the larynx.

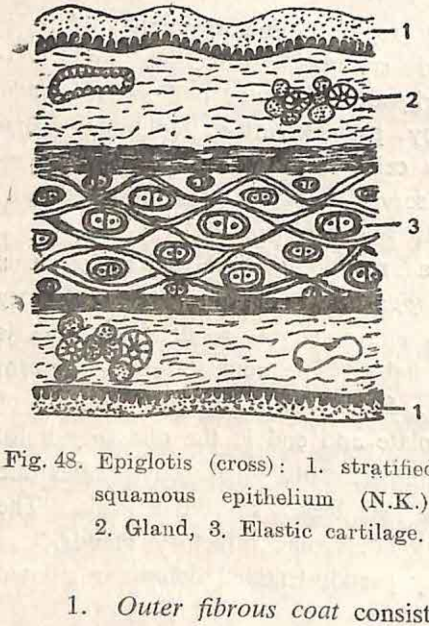


Fig. 48. Epiglotis (cross): 1. stratified squamous epithelium (N.K.), 2. Gland, 3. Elastic cartilage.

Features :

1. A central core of elastic cartilage covered with mucous membrane on both the surfaces.

2. The lining epithelium is non-keratinised stratified squamous epithelium which is thicker on the posterior surface due to constant friction with food. A few taste buds are present on the posterior surface.

3. The lamina propria contains mixed serous and mucous glands.

TRACHEA

Trachea has three layers :

1. *Outer fibrous coat* consisting mainly of elastic fibres.

2. *Intermediate coat* consisting of 16 to 20 incomplete ('C' shaped) rings of hyaline cartilages which are interconnected by elastic fibres. The posterior ends of the cartilages are connected by connective tissue and smooth muscle (*Trachealis muscle*).

3. *Inner mucous coat* consisting of :

(a) *Lining epithelium* : Pseudostratified columnar ciliated epithelium with intervening goblet cells.

(b) *Lamina propria.*: Contains mucous, serous and mixed glands, and abundance of elastic fibres ; also there is rich venous network to warm the inspired air.

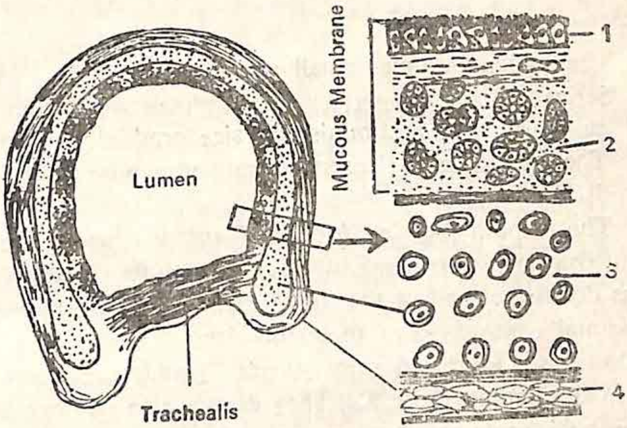


Fig. 49. T. S. of trachea: 1. Pseudo-stratified columnar ciliated epithelium, 2. Mixed glands in lamina propria, 3. Hyaline cartilage, 4. Fibrous coat.

Extrapulmonary Bronchi

Same structure as the trachea except size.

LUNGS

The lung is enclosed in a *serous coat* of pulmonary pleura, deep to which lies the *subserous coat* consisting mainly of elastic fibres. The pulmonary substance comprises of a system of *branching air* tubes (intrapulmonary bronchial tree) ending in multitudes of tiny pulmonary alveoli, together with blood vessels, lymphatics and nerves.

A microscopic section of lung shows a network of empty spaces surrounded by thin walls (i.e., alveoli) and contain different orders of bronchial tree (e.g., intrapulmonary bronchi, bronchole, respiratory bronchiole) and blood vessels.

Intrapulmonary Bronchial Tree comprises of :

A. Intrapulmonary bronchi, **B.** Bronchiole including terminal bronchiole, C. Respiratory bronchiole, **D.** Alveolar ducts, atria and alveolar sacs, E. Alveoli.

The conducting portion of bronchial tree ends at the terminal bronchiole; the respiratory portion begins with respiratory bronchiole and terminates at the alveoli.

A. Intrapulmonary bronchi includes lobar bronchi, segmental bronchi and bronchi of several orders each smaller than the previous one.

Features:

1. The lumen becomes small and circular.
2. Series of overlapping irregular plates of hyaline cartilage arranged circularly, which diminish in size gradually.
3. The epithelium is pseudo-stratified columnar ciliated with goblet cells.
4. The smooth muscle (*bronchial muscle*) lies in the deep part of the mucosa and is arranged in two long spirals running in opposite directions down the wall of the tube. In section the mucosa is folded due to agonal contraction of these muscles.
5. Mucous and mixed sero-mucous glands are present in fair number in the lamina propria. They decrease in number and in size as the bronchi grow smaller.

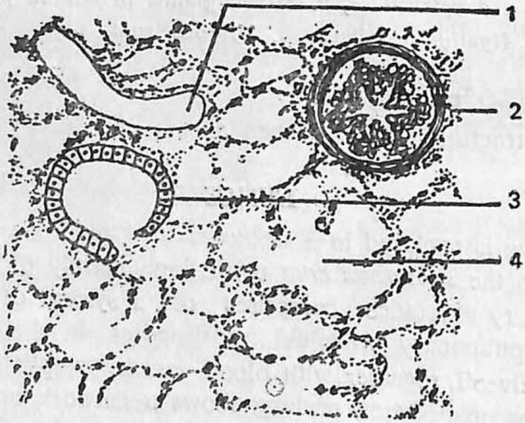


Fig. 50. Section of Lung: 1. Blood vessel, 2. Bronchiole 3. Respiratory bronchiole, 4. Alveoli.

B. Bronchiole

Bronchioles are air tubes with a diameter of about 1 mm. or less. The *epithelium is simple columnar ciliated*. Goblet cells become few and disappear in smaller tubes. Cartilage, glands and lymphoid tissue are absent. The wall of the bronchioles are primarily made of smooth muscle and elastic fibres. Upon death, contraction of these muscles cause the mucosa to be thrown into many folds.

The smallest bronchioles are called *terminal bronchiole*, which marks the end of purely conducting portion of bronchial tree.

C. Respiratory Bronchiole

Respiratory bronchiole begin with diameter of about .5 mm. or less. They are lined in their first part with simple columnar ciliated epithelium, which changes to simple cuboidal non-ciliated in smaller tubes. Cartilage, glands and goblet cells are absent. Smooth muscles and elastic fibres are spirally arranged. The wall of respiratory bronchiole is beset with a number of alveoli, which allow exchange of gases. These alveoli are responsible for the term respiratory bronchiole.

D. Alveolar Ducts, Atria & Alveolar Sacs

The *alveolar ducts* arise from respiratory bronchiole, and have thin walls studded with alveolar sacs and alveoli. The wall is supported by strands of elastic and smooth muscle fibres. In human beings atria are rare. *Smooth muscle is absent beyond the alveolar duct.*

Alveolar sacs arise from alveolar ducts and contain many alveoli. The lining epithelium is simple squamous in all the above three.

E. Alveoli

The alveoli are the ultimate subdivisions of the bronchial tree. They are *lined by simple squamous epithelium.* The alveoli are densely packed together, so that the *inter-alveolar septa* form a common wall between adjacent alveoli. These septa contain net work of elastic fibres and blood capillaries. The air within the alveoli is separated from the blood in the capillaries by : (i) alveolar epithelium, (ii) capillary endothelium and (iii) their fused basal laminae lying in between. Some minute *alveolar pores* about 8 to 10μ interconnect the alveoli, which provide collateral air circulation.

Other cells in the alveolar wall :

1. *Septal cells* are cuboidal cells. Their secretion forms a surface coating (*surfactant*) to the alveoli, which prevents them from collapsing when they recoil during expiration.

2. *Alveolar phagocytes* (*dust cells*) are found in the alveolar wall or free within the alveoli. They phagocytose dust particles. In certain cardiac diseases these cells become filled with hemosiderin granules and are termed '*heart failure cells*'.

Vessels and Nerves of Lung

The lung receives two sets of blood vessels : *pulmonary vessels* for respiration, and *bronchial vessels* for nutrition. The bronchial arteries supply the bronchial tree as far as the respiratory bronchioles. Lymphatics are absent from atria, alveolar sacs and alveoli, but are present elsewhere.

Both parasympathetic (vagal) and sympathetic fibres supply smooth muscles of bronchial tree and blood vessels. Vagal fibres are broncho-constrictor, while sympathetic fibres are broncho-dilator.

12 The Digestive System

The digestive system consists of a long muscular tube lined by mucous membrane. It begins at the lips and ends at the anus. Different functions have led to regional modification and specialization.

Parts

Mouth, pharynx, oesophagus, stomach, small intestine and large intestine. It also includes salivary glands, pancreas and liver.

Mouth

The mouth cavity is lined by non-keratinised stratified squamous epithelium.

A. **Lips & cheeks:** The substance is formed by skeletal muscles, covered on the outside by skin, and on the inside lined by non-keratinised stratified squamous epithelium, whch is thicker than the outer epidermis.

B. **Gum** consists of thick fibrous tissue covered by stratified squamous epithelium.

C. **Palate:** The central framework is formed by bone (hard palate) and muscle (soft palate) covered by mucous membrane. The oral surface and the lower most part of nasal surface has non-keratinised stratified squamous epithelium, the rest of nasal surface is lined by pseudostratified columnar ciliated epithelium. In lamina propria pure mucous glands on the oral side and mixed glands on the nasal side are present.

TEETH

A tooth is a modified papilla covered by a thick layer of calcified substance.

Parts

1. *Crown*: Projects above the level of the gum and is covered with enamel.
2. *Root* (one to three): Embedded in the alveolus.

3. *Neck*: Constricted part between crown and root, and is surrounded by gum-margin.

Periodontal membrane

It is the periosteum lining the alveolus and attaches the roots of the teeth to the alveolar sockets.

Structure

A tooth is composed of three hard substances—*enamel*, *cementum* and *dentine*, and contains a *pulp cavity*.

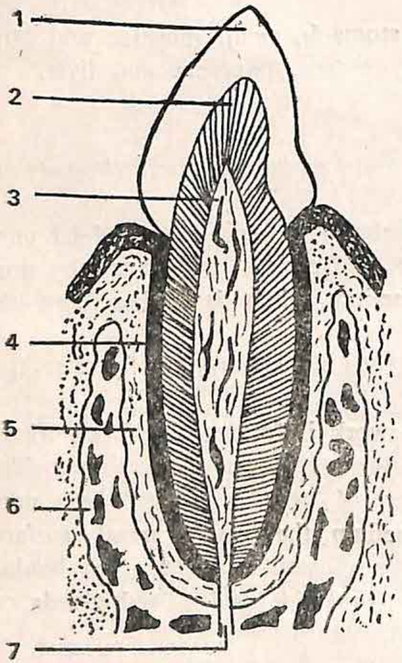


Fig. 51. Incisor teeth (L.S.): 1. Enamel, 2. Dentine, 3. Pulp, 4. Cementum, 5. Periodontal membrane, 6. Alvelous, 7. Apical foramen.

1. The *enamel* covers the dentine of the crown and is derived from *ectoderm*. It consists of radially arranged enamel prisms, which are bound together by cement substance. It is avascular, and is the hardest substance in the body.

2. The *cementum* surrounds the dentine of the root. It is a specialized calcified tissue which binds the root of the tooth to the surrounding periodontal membrane. It contains some bone cells but definite Haversian systems are usually absent.

3. The *dentine* forms the greater part of the tooth and encloses the pulp cavity. It is hard bone like but there are neither lacunae nor bone cells. It contains numerous dentinal canaliculi which begin at the pulp cavity and pass radially outwards to the dentino-enamel junction where they anastomose with one another. The canaliculi contain dentinal fibres, which are processes of odontoblasts lying in the pulp cavity.

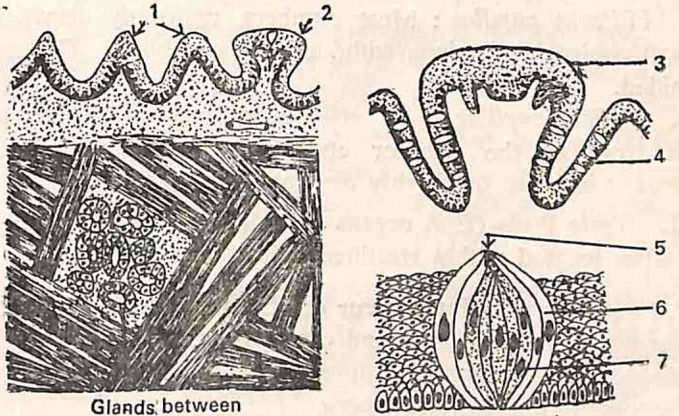
Pulp cavity and dental pulp

The pulp cavity extends into the root canals, at the tip of which is an apical foramen.

The dental pulp is vascular connective tissue containing vessels and nerves. A layer of columnar cells termed odontoblasts are arranged along the wall of the pulp cavity ; the vessels and nerves pass through the apical foramen at the root tip.

TONGUE

The tongue is a mobile muscular organ and consists of striated muscles covered with mucous membrane on both the surfaces.



Glands between muscle bundles

Taste bud

Fig. 52. Structure of tongue: 1. Filiform papillae, 2. Fungiform papilla, 3. Vallate papilla, 4. Taste bud, 5. Gustatory pore, 6. Supporting cells, 7. Gustatory cells.

A. Muscle :

The muscles of the tongue are striated and run in different directions. Serous and mucous glands are present between bundles of muscle fibres.

B. Mucous Membrane :

The mucous membrane is lined by non-keratinised stratified squamous epithelium. The anterior 2/3 of upper surface contains numerous *lingual papillae,* the posterior 1/3 has nodular elevations termed *lingual tonsils*, the lower surface has none.

I. Lingual Papillae are little projections of mucous membrane consisting of a central core of connective tissue covered with stratified squamous epithelium.

Types : Vallate, Fungiform, Filiform, Foliate.

1. *Vallate papillae* : Largest, 8 to 12 in number and situated in a row parallel to and in front of sulcus terminalis. Each papilla has a broad rounded top, a narrow base and is *surrounded by a circular groove*, whose outer wall is called *vallum*. Taste buds are present in the sides of vallate papilla and some in the vallum.

2. *Fungiform papillae* : Mostly present along the margins and tip of the tongue. They have broad rounded tops and a narrow base ; they contain some taste buds.

3. *Filiform papillae* : Most numbers, uniformly distributed, and are small conical projections without any taste buds. The epithelium is cornified.

4. *Foliate papillae* : A series of grooves and ridges immediately in front of the anterior ends of sulcus terminalis. They are rudimentary in man, but highly developed in rabbits.

II. Taste Buds (End organs of taste): They are lightly stained oval bodies located within stratified epithelium.

N.B : A few taste buds occur on the under surface of soft palate, posterior surface of epiglottis and oropharynx.

Shape : Flask shaped with a wide base and a narrow neck which opens at the *gustatory pore*.

Cell types : *Gustatory & supporting.*

The gustatory cells are fusiform cells and lie in the centre of the bud. These cells end in hair like filaments (*taste hairs*). The supporting cells are crescentic shaped and surround the gustatory cells.

III. Lingual Tonsils : These are nodular elevations in the dorsum of the pharyngeal part of the tongue. Each is an aggregation of epithelial pit surrounded by lymphoid tissue and lined with stratified squamous epithelium.

Glands of Tongue

(i) *Anterior lingual glands* (sero-mucous) near the apex embedded in the muscles.

(ii) *Serous glands* (of Von Ebner) near the vallate papillae.

(iii) *Posterior lingual glands* (mucous glands) near the root of the tongue.

PHARYNX

The pharynx is a common passage for food and air.

Parts : Nasopharynx, Oropharynx, Laryngopharynx.

The wall of the pharynx has 4 layers, from without inwards they are:

1. *Outer fibrous* coat formed by buccopharyngeal fascia.
2. *Muscle coat*: Skeletal muscles arranged in two ill-defined layers.
3. *Fascial coat* formed by pharyngobasilar fascia (mostly elastic fibres) is more prominent in the upper part.
4. *Inner mucous coat* :

(a) *Lining epithelium*—Pseudostratified columnar ciliated in nasopharynx; non-keratinised stratified squamous epithelium in oropharynx, laryngopharynx and also in the lower part of the nasal surface of soft palate.

(b) *Lamina propria*—Contains serous and mucous glands and collections of lymphoid tissue: pharyngeal tonsil in the posterior wall and tubal tonsils in the lateral wall of nasopharynx; palatine tonsil in the lateral wall of oropharynx.

GENERAL PLAN OF GASTRO-INTESTINAL TRACT

The gastro-intestinal tract has 4 coats, from without inwards they are: Serous, muscular, submucous and mucous coats.

A. Serous coat : Consists of a single layer of squamous cells (here called mesothelium) with a small amount of underlying connective tissue.

B. Muscular coat : Contains two layers of smooth muscles, outer longitudinal and inner circular. The circular layer is greatly increased at the sphincters.

The muscle coat causes peristalsis and also help in the mixing of the contents; sustained contraction control the size of lumen.

Myenteric plexus of Auerbach consisting of nerve fibres and ganglia are present between the longitudinal and circular muscles.

C. Submucous coat: Consists of loose connective tissue containing blood vessels and submucous nerve plexus (of Meissner).

D. Mucous coat (Mucosa) : Comprises of muscularis mucosae, lamina propria and the lining epithelium.

Mucosal folds in stomach and intestine, and villi in small intestine increase the surface area enormously.

1. *Muscularis mucosae* consists of two layers of smooth muscles. outer longitudinal and inner circular. Strands of muscle arise from

muscularis mucosae and extend into lamina propria between the glands or into the villi. It causes localized movement of the mucous membrane and mixes the contents.

2. *Lamina propria* contains many glands supported by connective tissue.

3. *Lining epithelium is mostly simple columnar* (except oesophagus and lower part of anal canal which have stratified squamous epithelium).

Glands are present:

(i) In the mucous coat.
(ii) In the submucous coat, chiefly in duodenum.
(iii) Outside the gut e.g., salivary glands, pancreas and liver.

Lymphoid tissue

Diffuse lymphoid tissue or solitary lymph nodules may be present in any part of the gut, mainly located in the mucosa.

Vessels

Portal system of veins carry products of protein and carbohydrate digestion; lymphatic carry products of fat digestion.

OESOPHAGUS

Oesophagus consists of usual 4 coats :

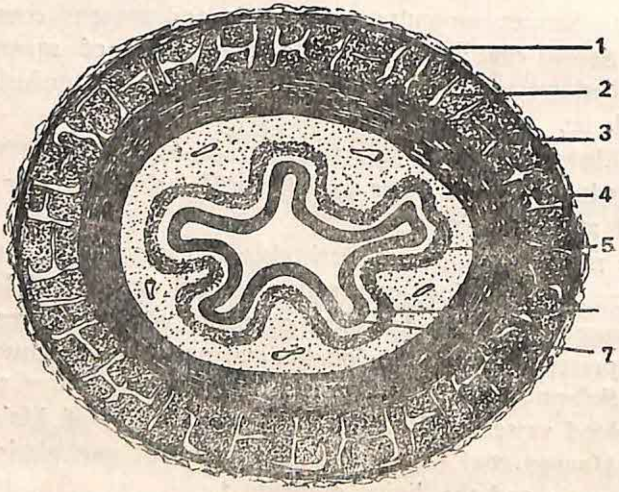


Fig. 53. T.S. of Oesophagus: 1. Fibrous coat, 2. Outer long. muscle, 3. Inner circ. muscle, 4. Submucous coat, 5. Muscularis mucosae, 6. Lamina propria, 7. Stratified squamous epithelium (N.K.)

A. *Fibrous coat* (in place of serous coat): Consists of connective tissue containing many elastic fibres ; the abdominal part has a serous coat.

B. *Muscular coat* : An outer longitudinal and an inner circular layers. In the upper 1/3 the fibres are skeletal, in the middle 1/3 mixture of skeletal and smooth muscles and in the lower 1/3 smooth muscle.

C. *Submucous coat* : May contain some mucous glands (oesophageal glands proper) specially in the upper part.

D. *Mucous coat*: Thrown into a number of longitudinal folds.

(i) The muscularis mucosae is prominent but contains only longitudinal fibres.

(ii) The lamina propria may contain few branched tubular glands (oesophageal cardiac glands) in the lower part.

(iii) Lining epithelium: Non-keratinised stratified squamous epithelum.

Histogenesis

The epithelium of oesophagus is entodermal. At first it is lined by a single layer of cuboidal cells; then becomes 2 layered in which the superficial cells are ciliated. Later ciliated cells disappear and the epithelium becomes stratified squamous.

STOMACH

Histological parts :

1. *Cardiac part* : 2 to 3 cm. surrounding the cardiac orifice.
2. *Fundic part* comprising of fundus and body of stomach.
3. *Pyloric part*.

The wall of the stomach consists of usual 4 layers.

A. *Serous coat* : As usual.

B. *Muscular coat* : Besides the usual two layers, longitudinal and circular, it has an innermost oblique layer. The pyloric sphincter is the thickening of circular muscle.

C. *Submucous coat* : As usual.

D. *Mucous coat* : The mucous coat is fairly thick ; when empty it shows numerous logitudinal folds termed *rugae*. The mucosa is beset with many small openings, the 'gastric pits' (foveolae), which serve as the ducts of gastric glands.

1. *Muscularis mucosae* : Well defined and borders the bases of gastric glands.

2. *Lamina propria* contains densely packed *gastric glands* particularly in the fundic region.

3. *Surface epithelium* : Lined by a single layer of tall columnar (mucous) cells which secrete mucous continuously. There are no goblet cells.

Glands of Stomach (Gastric Glands)

The gastric glands occupy the full thickness of mucosa and are bordered their bases by muscularis mucosae.

Types : *Cardiac, Fundic, Pyloric.*

I. The **cardiac glands** are confined to the cardiac part and contain mucous cells.

II. The **fundic glands** are found in the fundic part (fundus and the body). These are simple branched tubular glands. The secreting tubules are long, fairly straight and open at the bottom of gastric pits (duct) which are short.

Types of secreting cells : (a) Peptic cells, (b) Oxyntic cells, (c) Mucous neck cells and (d) Argentaffine cells.

(a) Peptic cells (Zymogenic or Chief cells) :

Location : Basal half of the glands.

Shape & size : Short columnar cells.

Cytoplasm : Basal part deep basic staining, the supranuclear part clear and vacuolated, but with proper staining secretion granules seen.

Secretion : *Pepsin.*

(b) Oxyntic cells (Parietal cells) :

Location : Numerous *in the neck of the gland.* Some are interspersed at the periphery of peptic cells.

Shape & size : Large oval cells with a central nucleus.

Cytoplasm : Fine acidophilic granules.

Secretion : Hydrochloric acid.

These cells contain intracellular canaliculi which pass between peptic cells and end in the lumen.

(c) Mucous Neck cells :

Location : Chiefly in the neck of gastric glands.

Shape & size : Large columnar cells.

Cytoplasm : Pale, with a basal nucleus.

Secretion : Mucus.

(d) Argentaffine cells : These occasional cells, contain fine silver-staining granules in the basal part of the cytoplasm. They produce 5-Hydroxy tryptamine.

III. **Pyloric glanls :** Present only in the pyloric part and are simple branched coiled tubular glands. The secreting tubules are short, and the pits (ducts) are much deeper than those of the fundic glands.

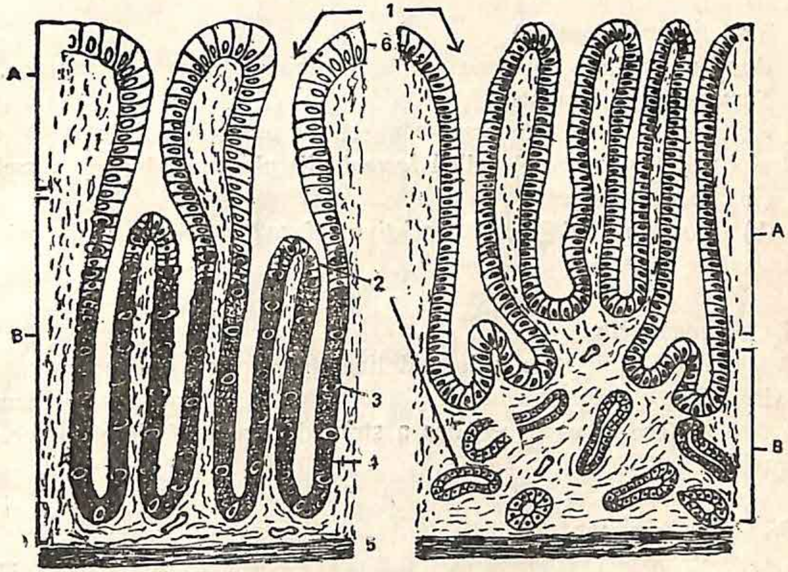


Fig. 54. Section of Stomach (Mucous coat only):— Left Fig. Fundic part ; Right Fig. Pyloric part. a—gastic pits (ducts), b—Secreting tubcles. 1, Gastric pits, 2. Mucous cell, 3. Oxynic cell, 4. Peptic cell, 5. Muscularis mucosae, 6. Simple columnar epithelium.

Cell type: Only mucoid cells similar to mucous neck cells of fundic glands.

SMALL INTESTINE

Parts : Duodenum, Jejunum, Ileum.

General Features of Small Intestine :

1. *Serous coat.*
2. *Muscular coat.* } as usual
3. *Submucous coat.*
4. *Mucous coat* : Characterized by *Villi*, intestinal glands and

mucous folds. The surface epithelium is reduced to small areas at the bases of villi between the mouths of intestinal glands. Plicae circulares are permanent transverse crescentic folds of mucous and submucous coats ; they increase the surface area.

Villi (villus—singular)

A villus is finger like surface projection of mucous membrane.

Structure : It consists of

(a) *Central core* of loose connective tissue containing (i) a central blind lymph vessel called *lacteal*, (ii) plexus of blood vessels and (iii) some muscles derived from muscularis mucosae.

(b) *Covering epithelium* consisting of *tall columnar cells* with some *goblet cells*.

Tall Columnar cells

These are absorptive cells and line the surface epithelium and the villi. The cytoplasm is finely granular having a basal oval nucleus. The free surface of each cell has a striated border of closely packed microvilli.

Goblet cells (see page 24)

Goblet cells are unicellular mucus secreting glands. They are found on the villi, the surface epithelium and in the glands, and progressively incrase in number from above downwards.

Intestinal glands (Crypts of Lieberkuhn)

These are simple tubular glands closely packed together in the lamina propria between the bases of villi.

Cell types :

(i) *Columnar cells* similar to surface cells but having short microvilli.

(ii) *Goblet cells.*

(iii) *Paneth cells* are pyramidal cells present at the bases of glands. They are serous cells with large acidophilic granules in the supranuclear part, the basal cytoplasm is basophilic. They produce digestive enzymes.

(iv) *Argentaffine cells* occur singly mainly in the glands, a few are present on the villi. They have tine silver staining granules in the subnuclear part.

Lamina propria : Occupies the space between the glands and forms the central core of the villi. It may contain diffuse lymphoid tissue with solitary lymph nodules at places; and it is limited by a thin muscularis mucosae.

Duodenum

1. Usual features of small intestine.

2. *Presence of duodenal glands of Brunner in the submucous coat.* These are compound tubular glands; secreting cells are mostly mucoid, some are serous cells. The ducts pierce the muscularis mucosae and mostly end in the intestinal glands. The secretion is alkaline which protects the duodenal mucosa from acid gastric juice.

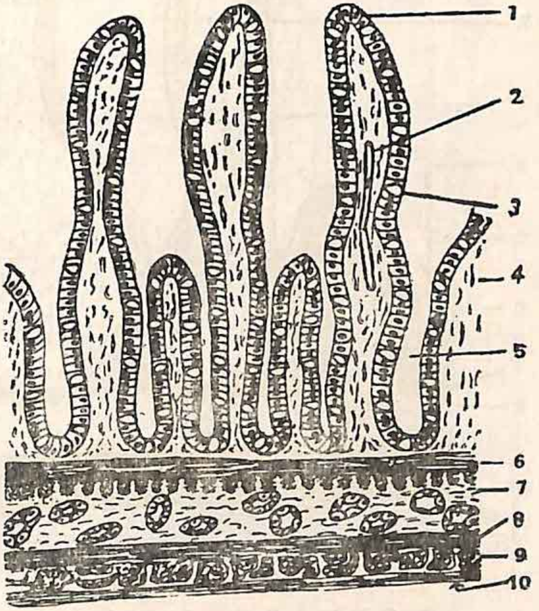


Fig. 55. T.S. of Duodenum: 1. Villus, 2. Lacteal, 3. Goblet cell, 4. Surface level, 5. Intestinal gland (crypt), 6. Muscularis mucosae, 7. Submucosal glands (of Brunner), 8. Inner circular muscle, 9. Outer longitudinal muscle, 10. Serous coat.

3. The villi are leaf like. The circular folds are absent from the first 2 cm. of duodenum.

Jejunum

Usual features of small intestine. The villi are longest and narrowest. But Brunner's glands and Peyer's patches are absent.

Ileum

1. Usual features of small intestine. The villi are shorter and club-shaped.

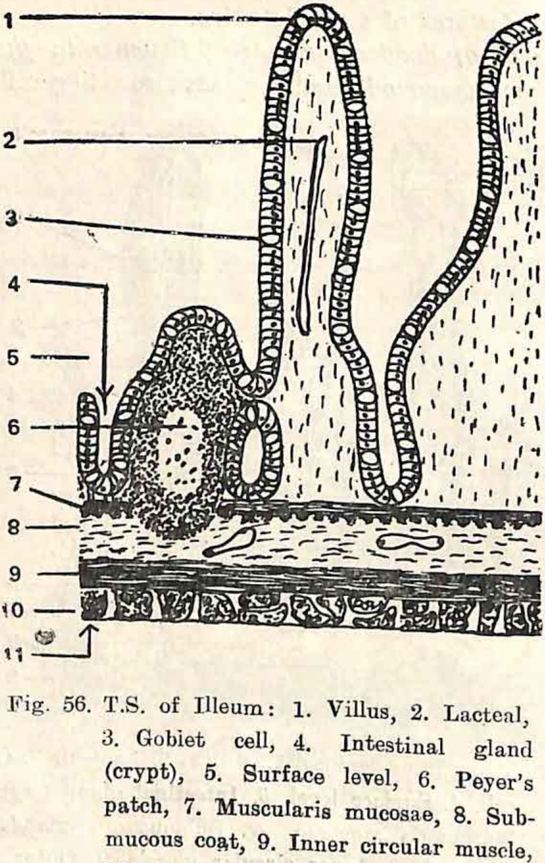


Fig. 56. T.S. of Illeum: 1. Villus, 2. Lacteal, 3. Gobiet cell, 4. Intestinal gland (crypt), 5. Surface level, 6. Peyer's patch, 7. Muscularis mucosae, 8. Submucous coat, 9. Inner circular muscle, 10. Outer logitudinal muscle, 11. Serous coat.

2. *Presence of aggregated lymph nodules* (*Peyer's patches*) located mainly in the mucous coat longitudinally on the antimesenteric border. They are oval groups of lymph nodules, which vary in size and commonly show germinal centres. These nodules, usually extend into the submucous coat. Villi and glands are usually absent from the nodular area, which becomes covered by simple columnar epithelium. There is no capsule, and they have only efferent lymphatic vessels. The nodules are the sites of ulceration in typhoid fever.

LARGE INTESTINE

Parts : Appendix, caecum, colon, rectum and anal canal.

The large intestine has the usual 4 coats of G.I.T. It is characterised by *complete absence of vill* and circular folds. The intestinal glands are longer and more densely packed and the goblet cells are greatly increased in number.

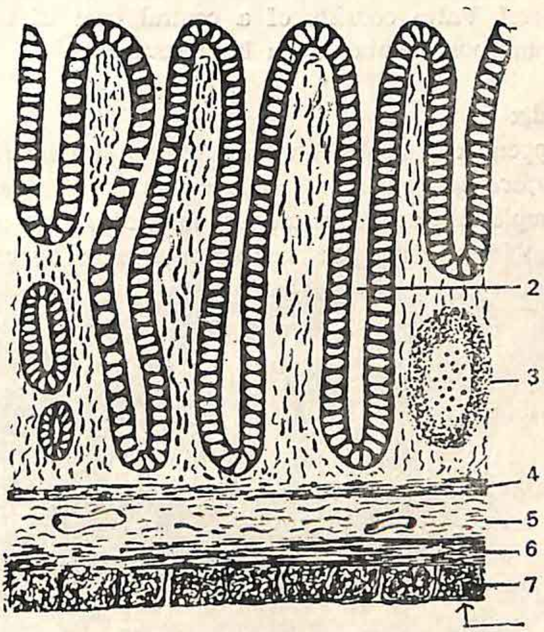


Fig. 57. T.S. of Caecum-Colon: 1. Surface epithelium, 2. Intestinal gland, 3. Solitary lymph nodule, 4. Muscularis mucosae, 5. Submucous coat, 6. Inner circular muscle, 7. Other longitudinal muscle, 8. Serous coat.

A. Caecum & Colon

1. *Serous coat* : Present only in part. Little pockets of peritoneum filled with fat termed *appendices epiploicae* are studded on the outer surface of colon.

2. *Muscular coat* : Presence of *taenia coli* which are three condensed bands of outer longitudinal muscle fibres and converge to the

base of the appendix. The taenia coli are shorter so the caecum and colon are sacculated.

3. *Submucous coat*: Usual features.

4. *Mucous coat*: Intestinal glands are longer and closely packed in vertical rows. Goblet cells increase considerably.

Solitary lymph nodules are more commonly seen.

Ileo-Caecal Valve consists of a central core of smooth muscle covered by mucous membrane on both surfaces.

B. Appendix

The appendix has relatively thick wall with a small lumen.

1. *Surface epithelium* is simple columnar with goblet cells.

2. Simple tubular glands are less numerous than colon and contain many goblet cells and fair number of argentaffine cells.

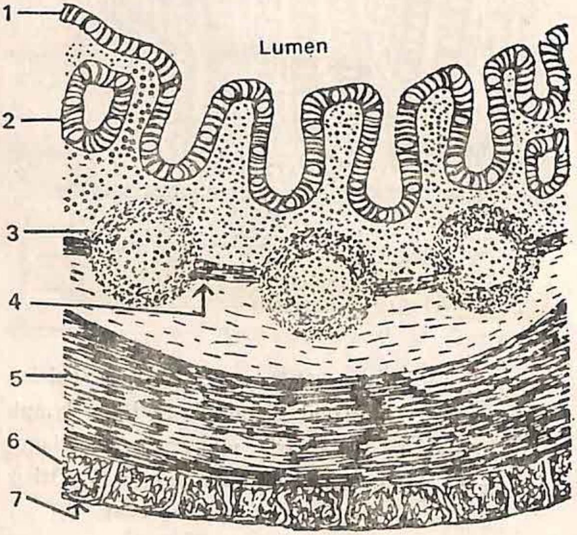


Fig 58. Appendix (cross): 1. Surface epithelium, 2. Intestinal gland, 3. Lymph nodules, 4. Deficient muscularis mucosae, 5. Inner circular muscle, 6. Outer longitudinal muscle, 7. Serous coat.

3. The main mass of mucosa is occupied by many lymph nodules which extend into the submucous coat. Usually these nodules are confluent and surround the lumen like a lymphoid ring.

4. The muscularis mucosae is poorly developed and present at intervals between the lymph nodules.

C. Rectum

The rectum has no taenia coli, no sacculations, no mesentery, no appendices epiploicae.

The surface epithelium is simple columnar ; intestinal glands are longer and goblet cells increase to a maximum. Temporary longitudinal folds, and permanent horizontal folds formed by mucosa, submucosa and circular muscles are present.

D. Anal Canal

A. Mucous Membrane

1. *In upper 15 mm* : Lining epithelium simple columnar with numerous goblet cells. Intestinal glands are present. Presence of anal columns — 6 to 10 vertical folds of mucous membrane ; Anal valves join the lower ends of anal columns. Anal sinus lies above each valve, in which open the ducts of anal glands located between the internal and external sphincters.

2. *Succeeding 15 mm.* (Transitional zone): The epithelium is stratified but there are no sweat glands. A narrow wavy line termed Hilton's line marks the lower limit of transitional zone.

3. *Lower 8 mm* : Lined by true skin and contains apocrine sweat glands and sebaceous glands.

B. Muscles : In upper 2/3 circular smooth muscle thickens to form internal sphincter. The external sphincter is composed of skeletal muscle and surrounds the whole anal canal. Between the two is the longitudinal conjoint muscle coat composed of both smooth and skeletal muscles.

GLANDS ASSOCIATED WITH DIGESTIVE TRACT

Besides numerous glands located in the gut wall (mural glands), some lie outside the confines of the digestive tube (extramural glands) but deliver their secretions into it through ducts. The extramural glands include salivary glands, pancreas and liver.

Salivary Glands

All salivary glands are merocrine, compound tubulo-alveolar glands.

Classification : Based on secretory cell types and nature of secretion :

A. *Serous Salivary gland* : Contains only serous secreting cells e.g., parotid gland.

B. *Mucous Salivary gland* : Contains mucous secreting cells, e.g., posterior lingual glands.

C. *Mixed Salivary gland* : Contains both serous and mucous cells e.g., submandibular and sublingual salivary glands.

PAROTID GLAND (Serous salivary gland)

A. Connective Tissue Framework : Well defined fibrous *capsule ;* septa pass inside and divide the gland into *lobules.* Each lobule consists of numerous alveoli and small ducts.

B. Parenchyma (Glandular substance): Comprises *alveoli* and *duct system.*

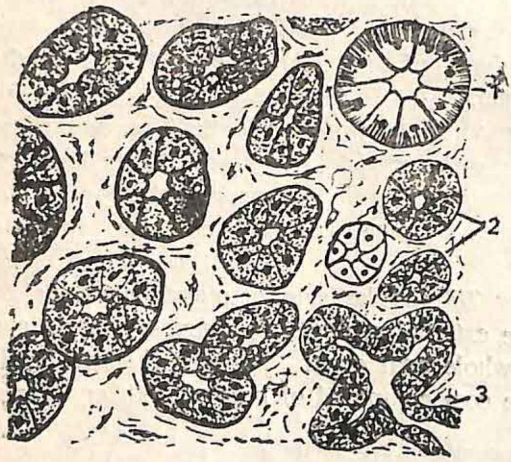


Fig. 59. Section of Parotid gland: 1. Striated duct, 2. Serous alveoli, 3. Intercalated duct.

I. Alveoli

Each alveolus is lined by a single layer of serous cells; the lumen is small or obliterated.

Features of Serous cells:

(i) Small polyhedral, usually smaller than mucous cell.

(ii) Nucleus: Spherical and placed near the centre of the cell.

(iii) Cytoplasm: The supranuclear part contains eosinophilic zymogen granules (precursor of ptyalin), basal part takes a deep basic stain.

Basket cells : These are spindle shaped cells with many long cytoplasmic processes, and lie between the bases of secretory cells and the basal lamina. The cells are of epithelial origin but contain myofibrils in their cytoplasm and help in the expulsion of secretion.

II. Duct System

The parotid gland has *prominent duct system.* The alveoli open into *intercalated ducts* lined by low cuboidal epithelium. The *striated (intralobular) ducts* are lined by simple columnar epithelium ; the basal part of these cells show parallel acidophilic striations and is indicative of some secretory activity. The *excretory ducts (intralobular)* are lined by pseudo-stratified columnar epithelium. The lumen of both intra and interlobular ducts are large and regular. The parotid duct at the point of its opening into the mouth is lined by stratified squamous epithelium.

SUBMANDIBULAR SALIVARY GLAND (Mixed salivary gland)

A. Connective Tissue Framework : Similar to parotid gland.

B. Parenchyma (Glandular Substance) : Comprises *alveoli* and *duct system.*

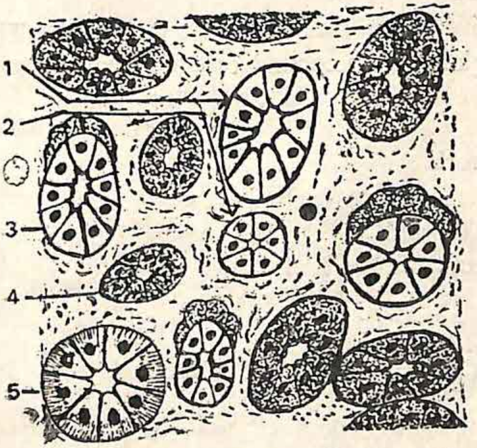


Fig. 60. Section of Submandibular salivary gland : 1. Mucous alveolus, 2. Intercalated duct, 3. Mucous alveolus with serous crescent, 4. Serous alveolus, 5. Striated duct.

I. Alveoli

The alveoli contain cells of two types: (a) serous cells (see parotid gland) and (b) Mucous cells.

Features of mucous cell:

(i) Large and polyhedral.

(ii) Nucleus: Flattened and applied to the base.

(iii) Cytoplasm: Appears pale and vacuolated (net like) due to precipitation of mucin. In fresh condition the cytoplasm contains large granules of mucinogen.

Many alveoli are purely serous, some purely mucous and some are mixed with serous crescents. Mucous alveoli have prominent lumen.

Serous crescents (Demilunes of Gianuzzi): These are groups of serous cells arranged like a cap on the mucous alveoli and are located between the secretory mucous cells and the basal lamina. Fine canaliculi (intercellular) pass between mucous cells to conduct the secretions of serous cells into the lumen.

Basket cells are present between gland cells and basal lamina. (see parotid gland).

II. Duct System

Similar to parotid gland but the intercalated ducts are less developed.

SUBLINGUAL SALIVARY GLAND (Mixed salivary gland)

The sublingual salivary gland is a mixed salivary gland, but majority of the alveoli are of mucous type. Some mucous units have serous crescents. Intercalated ducts are absent and striated ducts are few in number.

PANCREAS

The pancreas is both an exocrine and an endocrine gland. The exocrine part is a digestive gland, a compound tubulo-alveolar gland. The endocrine part, the islets of Langerhan's, produces insulin.

A. Connective tissue framework

1. Thin connective tissue capsule enclosing the gland.
2. Thin septa pass inside and divide the organ into lobules which contain numerous alveoli and the islets.

B. Exocrine part

It is a purely serous gland and consists of alveoli (acini) and their ducts.

1. Alveoli

The cell boundary is not distinct. The alveoli are lined by a single layer of serous cells, with a very small lumen. A rounded nucleus lies near the base. The basal cytoplasm is basophilic due to abundant granular endoplasmic reticulum. The supranuclear part of the cell contains acidophil zymogen granules.

2. Ducts

The *intra* and *interlobular ducts* are lined by low columnar cells. *As compared with salivary glands, ducts are few in pancreas.* Intercalated ducts lined by flattened cells lie between the intralobular ducts and the alveoli (acini). Some parts of these ducts are invaginated into the lumen of some acini. These ducts within the lumen of the acini are termed *centro-acinar cells.* The main pancreatic luct is lined by single layer of columnar cells.

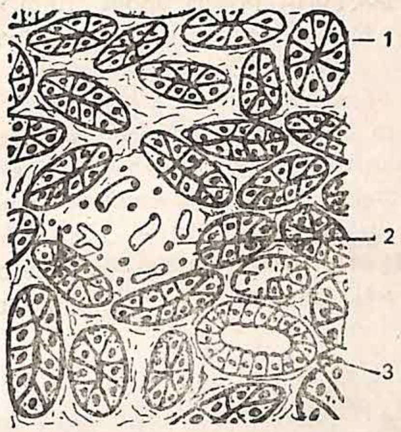


Fig. 61. Section of Pancreas: 1. Serous alveolus, 2. Islet of Langerhan's, 3. Duct.

C. Endocrine part: (Islets of Langerhan's)

These are lightly stained groups of epithelial cells arranged around the sinusoids and supported in a reticular framework. The islets are unevenly scattered in the lobules.

Cell types :

1. Alpha ∝ Cells : The granules are water soluble. They secrete *glucagon*, whose action is antagonistic to that of insulin.

2. Beta (β) cells : Most numerous; the granules are alcohol soluble. cells secrete insulin which lowers blood sugar level. Deficiency results in Diabetes mellitus.

3. Delta (∂) cells are few in number. Function is not known.

LIVER

The liver is the largest gland in the body and secretes bile. Besides, it has many other functions. It is essential to life, has great physiological reserve and great regenerating power.

A. Connective Tissue Framework

(i) *Fibro-elastic capsule* (Glisson's capsule) deep to visceral peritoneum.

(ii) *Incomplete septa* divide the substance (parenchyma) of the liver into millions of *hepatic lobules.* These septa are largely limited to the edges of hepatic lobules, where they form perivascular fibrous capsule surrounding the portal canals.

(iii) *Reticular fibres* support the sinusoids and hepatic laminae.

B. Hepatic Lobule (Classical Lobule)

The hepatic lobules are little polygonal prisms about 2 mm. × 1 mm. *In section* they are usually hexagonal, having following features.

1. *A central vein* in the centre of each lobule.
2. *Liver cells* in the lobule are arranged in *irregular radiating cords,* one cell thick and extend from the central vein to the periphery of the lobule. They represent sections of *hepatic laminae*.
3. *Sinusoids* are located between the cords of liver cells.
4. *Portal canals* (portal triad) are present at the edges of hepatic lobules. Each canal contains (i) interlobular branch of portal vein of large size with thin wall, (ii) Interlobular branch of hepatic artery of small size but thick wall, (iii) Interlobular bile ductule lined by a single layer of cuboidal cells, and (iv) a lymph vessel. These structures are surrounded by connective tissue septa termed perivascular fibrous capsule.

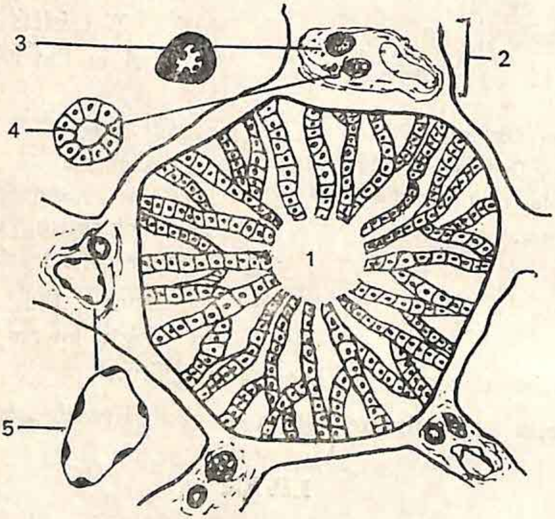


Fig. 62. Section of liver : 1. Central V, 2. Portal canal, 3. Branch of hepatic A, 4. Bile ductule, 5. Branch of portal V.

The portal canals are surrounded by a limiting plate one cell thick which are perforated by branches of blood vessels and bile ductules. Between the limiting plate and the perivascular capsule is the *periportal space of Mall.*

Portal Lobule comprises adjoining parts of three hepatic lobules and are arranged with reference to exocrine function, the bile ductule in the portal canal forming its central axis. It is triangular in shape and is formed by joining three adjacent central veins.

Hepatic laminae

The liver cells (polyhedral in shape with vesicular nucleus, sometimes binucleate) are arranged in irregular branching and anastomosing cellular plates, one cell thick called *hepatic laminae*, which radiate from the central vein to the periphery of the hepatic lobule. Adjoining laminae are interconnected by interlaminar bridges of liver cells. In section the laminae appear as radiating cords of liver cells. The laminae are perforated and thus a sysetm of intercommunicating cavities termed *lacunae* are present between the laminae, which contain hepatic sinusoids. The whole arrangement gives a sponge like (muralium) appearance.

Hepatic sinusoids

The hepatic sinusoids are situated between the laminae and anastomose with one another through perforations in the laminae. The sinusoids are lined by two types of cells : *Endothelial cells* and *phagocytic stellate cells of Kupffer*. The latter cells are large cells with well defined processes and play an important role in the formation of bile pigments. The sinusoids are separated from the hepatic laminae by a potential space, the *perisinusoidal space of Disse*, which is continuous with *periportal space* through perforations in the limiting plate.

Blood Circulation: At the periphery of the lobule the

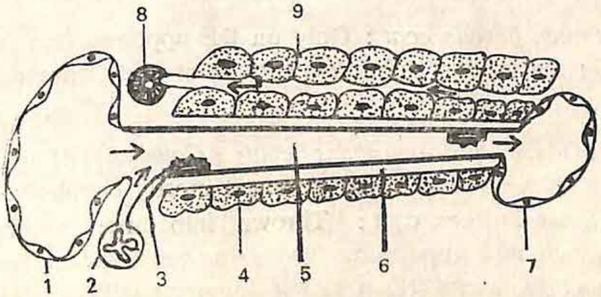


Fig. 63. Circulation through Liver: 1. Branch of portal V., 2. Branch of hepatic A., 3. Kupffer's cell, 4. Cord of liver cells, 5. Sinusoid, 6. Perisinusoidal space, 7. Central vein, 8. Bile ductule, 9. Bile Canaliculi.

sinusoids receive blood from portal vein (75%) and hepatic artery (25%). The sinusoids pass radially inwards and end in the central veins. They join to form sublobular veins, which in turn unite to form hepatic veins.

Bile Passages

The bile passages begin as bile canaliculi which run between the apposed surfaces of adjacent liver cells, except on the surfaces in contact with the sinusoids. E M shows that *the wall of bile canaliculi is formed by thickened surfaces of adjacent cell membranes of liver cells*. Draining towards the periphery of the lobule, the bile canalicull join to form intralobular bile ductule, which enter the portal canal by perforating the limiting plate and join the interlobular bile ductule (lined by simple cuboidal epithelium). These in turn join to form larger ducts and finally the right and left hepatic ducts emerge from the liver.

Lymph vessels

Some lymph vessels arise from the peripheral part of the perisinusoidal space, but mostly from the periportal space.

GALL BLADDER

The gall bladder is a pear shaped sac that *stores and concentrates bile*. Capacity about 50 ml.

Parts: Fundus, Body and Neck.

Features

1. *Outer fibrous coat*: Only on the upper surface of the body and neck; the fundus and lower surface of body have a serous coat, in addition.

2. *Middle fibro-muscular coat*: Consists of smooth muscle mixed with fibrous tissue, and arranged mostly circularly.

3. *Inner mucous coat*: Thrown into large number of folds which branch and anastomose giving a reticulated (honeycombed) appearance. The epithelium is tall columnar with a very thin striate border composed of a few short microvilli. Glands are absent except a few at the neck. *There is no muscularis mucosae.*

Functional Aspect: Cholecystokinin produced by duodenal mucosa controls the discharge of bile into the duodenum.

Extra Hepatic Ducts (hepatic, cystic and common bile ducts)

They have thick fibro-elastic coat lined by tall columnar cells.

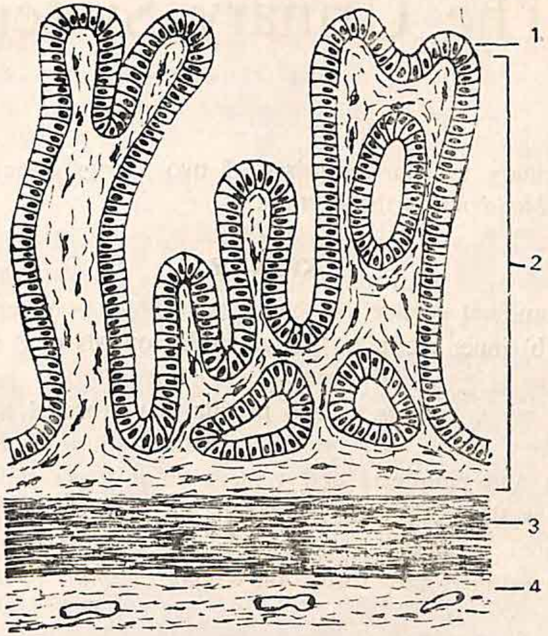


Fig. 64. Gall Bladder (cross): 1. Simple columnar epithelium, 2. Mucous coat, 3. Fibro-muscular coat, 4. **Fibrous coat.**

Thickened smooth muscle fibres form sphincter of Boyden in the terminal part of common bile duct.

13 The Urinary System

The Urinary system comprises of two *kidneys*, the two *ureters*, the *urinary bladder* and the *urethra.*

KIDNEY

A longitudinal section of the kidney shows two parts (a) outer cortex and (b) inner medulla. The *medulla* consists of 8 to 18 conical masses, the *renal pyramids*, their apices form renal *papilla* which project into *minor calyces.* Each papilla is perforated by some 10 to 25 *papillary ducts.* The medulia contains loops of Henle, collecting tubules and parallel blood vessels, so it looks radially striated. The cortex is the peripheral part lying between the capsule and the bases of renal pyramids; a part of cortex projects inwards between the renal pyramids and form the *renal columns of Bertin.* The cortex contains renal corpuscles, and the convoluted tubules and so it looks dark and granular. The cortex also contains *medullary rays* (i.e., collecting tubules) which are extensions from the pyramids of the medulla.

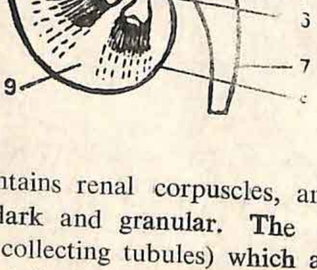


Fig. 65. L. S. of Kidney: 1. Cortex, 2. Medulla (Pyramid), 3. Calyx minor, 4. Calyx major, 5. Pelvis of Kidney, 6. Renal papilla, 7. Ureter, 8. Capsule, 9. Renal column.

A. Connective tissue framework

The kidney is covered by a capsule of connective tissue consisting of collagen, elastic and smooth muscle fibres. The interstitial connective tissue supporting the uriniferous tubules consists of reticular tissue mainly.

B. Uriniferous Tubules

Each kidney contains large number of tortuous closely packed uriniferous tubules each of which consists of two parts : I. *Nephron* and II. *Collecting tubules*. The two parts arise from separate primordia, which unite later on.

I. Nephron

The nephron is the structural and functional unit numbering about a million in each kidney.

Parts : Renal corpuscle, Proximal convoluted tubule, Loop of Henle, Distal convoluted tubule and a short Junctional tubule.

1. **Renal corpuscles** (Syn. Malpighian corpuscles) :

The renal corpuscles are small rounded bodies present in all parts of the cortex including the renal columns. Each is composed of two parts : (a) Glomerulus, (b) Bowman's capsule.

(a) The *glomerulus* is a lobulated tuft of capillaries supplied by a wide afferent arteriole and drained by a narrow efferent arteriole. The endothelial cells lining the glomerular capillaries are perforated by numerous circular pores.

(b) The *Bowman's capsule* is the blind expanded end of the nephron and is invaginated by the glomerulus. It is a double walled epithelial cup consisting of (i) a parietal layer lined by simple squamous epithelium, and (ii) a visceral layer in contact with the glomerular capillaries and is lined by modified cells termed the *podocytes*. The podocytes have major processes which give rise to minor foot-like processes termed *pedicels,* which are attached to the wall of the capillaries. Between the adjoining pedicels there are little spaces termed *filteration slits*. The fused basal laminae form the dialysing membrane between the blood and the glomerular filterate.

The renal corpuscle has a *vascular pole* where the afferent and efferent vessels enter and leave the glomerulus; and a *urinary pole* where the capsular space (space between the visceral and parietal layer of Bowman's capsule) is continuous with the proximal convoluted tubule.

2. Proximal convoluted tubule

Location: In the cortex.

Lumen: Small.

Lining epithelium : Single layer of large cuboidal (truncated pyramidal) cells, the *luminal surface* of each cell bears a prominent 'brush border' of closely packed microvilli rich in alkaline phosphatase, the basal plasma membrane shows parallel folds; nucleus rounded, and cytoplasm deep eosinophilic.

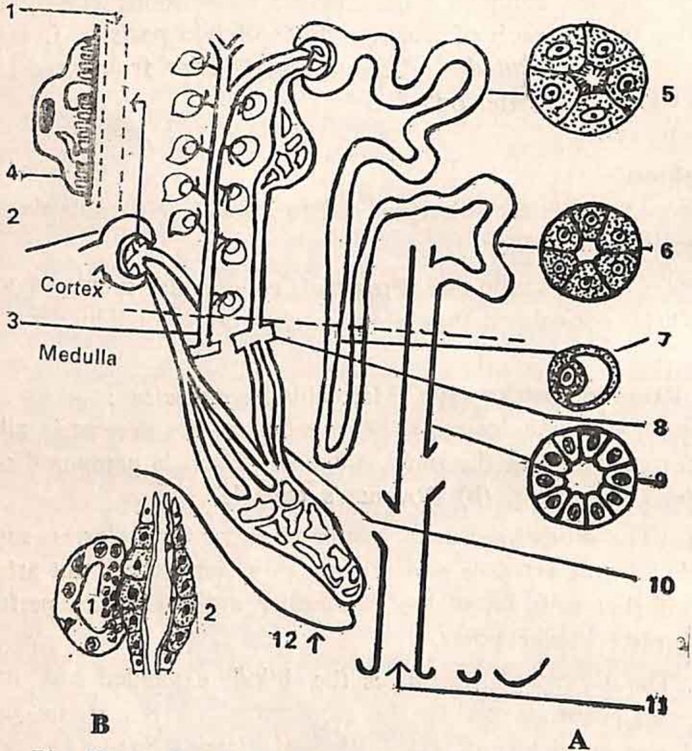


Fig. 66. A. Parts of **Nephron** and Vascular supply: 1. Capillary of glomerulus, 2. Renal corpuscle, 3. Interlobular artery, 4. Podocyte, 5. Proximal convoluted tubule, 6. Distal convoluted tubule, 7. Thin segment (of Henle's loop), 8. Arcuate vessels, 9. Collecting tubule, 10. Vasa recta, 11. Papillary duct, 12. Renal papilla.
B. Juxtaglomerular apparatus: 1. Macula densa, 2. Juxtaglomerular cells.

3. Loop of Henle

Location : Partly in the cortex, mainly in the medulla, and has a descending and an ascending limb.

Descending limb : Lined in the upper part by simple cuboidal epithelium, but the major lower part by simple squamous epithelium.

Ascending limb: Simple squamous epithelium in the lower part, but simple cuboidal epithelium in the major upper part.

Thus the Henle's loop has three segments: descending thick segment, thin segment and ascending thick segment.

Types of loop : Short and long; nephrons located high in the cortex have short loops, while nephrons located near the medulla have long loops.

4. Distal convoluted tubule

Location: In the cortex near the vascular pole between the two arterioles of its own glomerulus.

Lumen : Large.

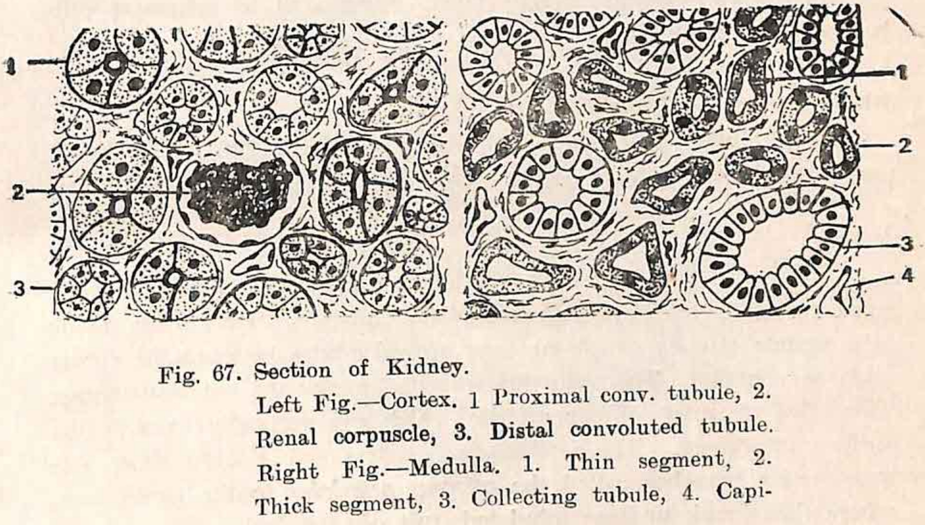


Fig. 67. Section of Kidney.
Left Fig.—Cortex. 1 Proximal conv. tubule, 2. Renal corpuscle, 3. Distal convoluted tubule. Right Fig.—Medulla. 1. Thin segment, 2. Thick segment, 3. Collecting tubule, 4. Capillary.

Lining epithelium : Single layer of small cuboidal cells. There is no brush border (but in E M few short microvilli seen), the basal plasma membrane shows extensive folds ; cytoplasm less eosinophilic.

Juxtaglomerular Apparatus

Juxtaglomerular apparatus is the modification of the distal convoluted tubule and the afferent arteriole at the region of their contact and comprises of :

(a) *Macula densa* is the thickened area in the wall of distal convoluted tubule ; the cells become columnar and there is crowding of the nuclei.

(b) *Juxtaglomerular cells* are the modification of the smooth muscle cells in the tunica media of afferent arteriole. These smooth muscle cells become epitheloid cells, the cytoplasm of which contains many granules (juxtaglomerular granules) in place of myofibrils. These cells respond to a fall in blood pressure by secreting renin.

5. A small junctional tubule connects the nephron with the straight collecting tubule located in the medullary ray of the cortex.

II. Collecting Tubules

The collecting tubules pass inwards in the medulla and join with similar tubules several times ; finally the papillary ducts of Bellini are formed, 10 to 25 of which open at the apex of each renal papilla.

Lining epithelium : Single layer of cuboidal to columnar cells having *clear cytoplasm*.

Blood Vessels of Kidney

The kidney has a rich blood supply. About 1200 ml. of blood pass through both kidneys each minute.

Arteries

The renal artery gives off interlobar arteries, which pass between renal pyramids to the cortico-medullary junction. Here they divide into arcuate arteries which takes an arched course between the cortex and the medulla. The adjoining arcuate arteries do not anastomose. They give off inter lobular arteries which run vertically towards the surface of kidney. The interlobular arteries give rise to short side intralobular branches called the *afferent arterioles* to the glomerulus, where they break up into lobulated tuft of capillaries. The efferent arteriole and its further course differs according to the situation of the glomeruli, cortical and juxtamedullary :

(a) In *cortical glomeruli*, the efferent arteriole has a smaller lumen than the afferent arteriole. This inequality serves to promote the filtration pressure in the glomeruli. The efferent arteriole breaks up into a second series of capillaries (peritubular) around the neighbouring convoluted tubules. This second capillary bed contains blood at low pressure but high colloidal osmotic pressure which help in tubular reabsorption.

(b) In *Juxtamedullary glomeruli*, the efferent arteriole is of the same calibre as the afferent. Here the efferent arteriole breaks up into a leash of straight parallel vessels, the *vasa recta,* which run down into the medulla between the loops of Henle and the collecting tubules. They form hairpin loops in the medulla and return to the cortico-medullary junction, where they unite to form venules that enter the arcuate vein. *These blood vessels are the only source of blood supply to the medulla.*

Veins

The interlobular veins receive capillary bed of the cortex and the stellate veins from the capsule. These veins end in arcuate veins which also receive the *venulae rectae.* The arcuate veins join to form interlobar veins which in turn unite to form the renal vein.

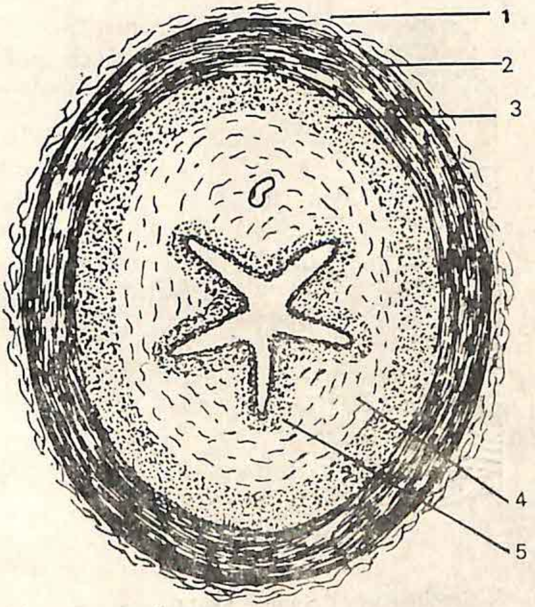


Fig. 68. T.S. of Ureter: 1. Fibrous coat, 2. Outer circular muscle, 3. Inner longitudinal muscle, 4. Lamina propria, 5. Transitional epithelium.

Calyx Minor and Major are lined by transitional epithelium consisting of 2 to 3 layers of cells.

URETER

The ureter, about 25 cm. long, connects the kidney with the urinary bladder. It has 3 layers :

1. *Outer fibrous layer* : Consists of collagen and elastic fibres.
2. *Middle muscular layer* : Consists of bundles of smooth muscle with intervening connective tissue. In the upper 2/3 the ureter has two muscle layers, outer circular and inner longitudinal ; in the lower 1/3 there is an additional outermost longitudinal layer.
3. *Inner mucous layer* : Shows 4-5 longitudinal folds giving the *small lumen star shaped* appearance. The mucosa is lined by transitional epithelium having 4 to 5 layers of cells.

URINARY BLADDER

The urinary bladder is a sac which stores urine. It is composed of the same three layers as the lower part of the ureter, but is much thicker.

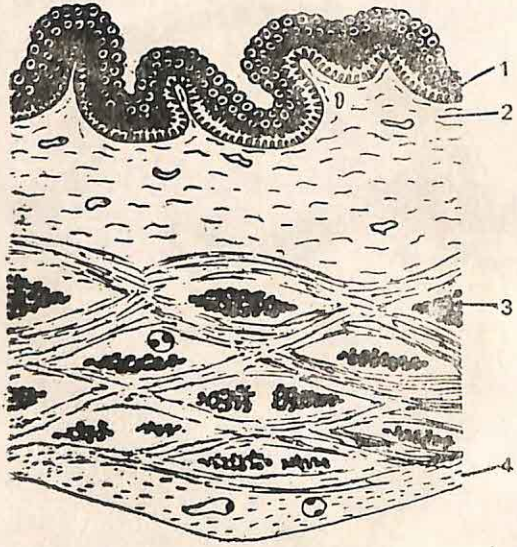


Fig. 69. Section of Urinary bladder. 1. Transitional epithelium, 2. Lamina propria, 3. Muscle coat, 4. Fibrous coat.

1. *Outer fibrous layer* : But upper surface has a serous coat.
2. *Middle muscular layer* (Detrusor muscle) : Thick and consists of 3 ill-defined sublayers with intervening connective tissue ; outer and inner longitudinal, middle thick circular ; the circular layer thickens

to form internal sphincter near the urethral orifice. Numerous ganglia are present in the connective tissue.

3. *Inner mucous layer* : Thrown into many folds termed *rugae;* lining epithelium is transitional having 6 to 8 layers of cells; lamina propria loose. ***Mucous glands are absent,*** but some may be found near the urethral orifice.

URETHRA

The urethra conveys urine from the urinary bladder to the outside. In male, it also serves a passage for semen.

Male Urethra

The lining epithelium is transitional in the prostatic part, stratified columnar or pseudostratified columnar in the membranous part and most of cavernous part, and stratified squamous near the external opening. **Intra-epithelial glands** are common. Mainly in the cavernous part, the lamina propria contains many urethral glands (of Littre) lined by mucus secreting columnar cells.

Female Urethra

The lining epithelium is transitional near the bladder. next stratified or pseudostratified columnar and finally stratified squamous near the outlet. The lamina propria resembles the erectile tissue of penis and contains urethral mucous glands, and para urethral glands (of Skene) homologous to prostate.

CHART SHOWING DIFFERENCES BETWEEN CORTICAL AND JUXTAMEDULLARY GLOMERULI

	Cortical glomeruli	*Juxtamedullary glomeruli*
1. Loop of Henle	Short.	Long.
2. Efferent arteriole	(i) Small than afferent. (ii) Breaks up into peritublar plexus.	(i) Equal to afferent. (ii) Forms a leash of parallel vessels (Vasa recta).
3. Blood received from	Peripheral parts of interlobular arteries.	Proximal parts of interlobular arteries.
4. Post-glomerular capillary bed	Rich.	Less ; vasa recta form the medullary vascular bed.

14 Male Reproductive System

The male reproductive system comprises

1. Paired testes.
2. Male genital ducts : Vasa efferentia, epididymis, vas deferens and ejaculatory ducts.
3. Accessory glands : Seminal vesicle, prostate and bulbo urethral glands, which provide fluid medium for the sex cells.
4. Copulatory organ : The penis.

TESTIS

The testes are paired ovoid male sex glands situated in the scrotum. They are compound tubular glands having two fold functions from puberty onwards : Production of *spermatozoa* and the male sex hormone *testosterone*.

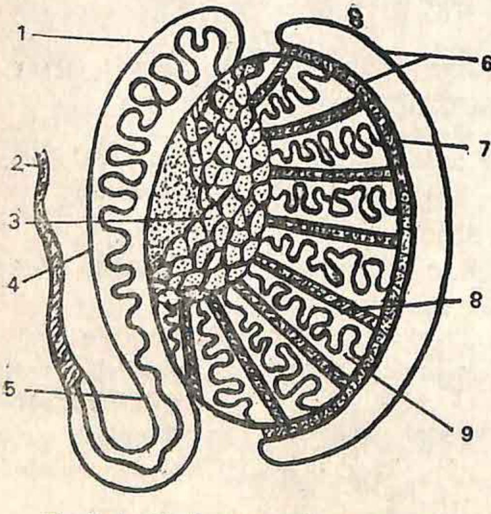


Fig. 70. L.S. of Testes and Epididymis, 1. Head of epididymis, 2. Vas deferens, 3. Rete testes, 4. Body of epididymis, 5. Tail of epididymis, 6. Tunica vaginalis, 7. Tunica albuginea, 8. Septum testes, 9. Seminiferous tubule.

Each testis is covered on its front and sides by a serous mesothelium, termed the visceral layer of *tunica vaginalis* derived from processus vaginalis of the peritoneum. Deep to this the whole gland is enclosed by a thick fibrous capsule, the *tunica albuginea*, the deep layer of which is very vascular. Posteriorly, the tunica albuginea projects inwards like a thick fibrous septum, the *mediastinum testis*. Many thin fibrous septa (septula testis) extend from the mediastinum testis to the tunica albuginea and subdivide the tesis into 200 to 300 cone shaped *lobules*. Each lobule contains 1 to 3 highly convoluted *seminiferous tubules*, and the *interstitial tissue* in between them. At the apex of the lobules the convoluted siminiferous tubules become *straight tubules*, which enter the mediastinum testis, where they form a network, the *rete testis*. About 12 to 15 efferent ductules (*vasa efferentia*) connect the rete testis with the head of the epididymis.

A. Interstitial Tissue

The interstitial tissue occupies the space between the seminiferous tubules and consist of interstitial cells of Leydig in the loose vascular connective tissue. The Leydig cells are large oval cells with large spherical nuclei and acidophilic cytoplasm. Many of these cells contain rod shaped crystals (of Reinke). The *interstitial cells form the endocrine part of the testis and produce testosterone*.

B. Convoluted Seminiferous Tubules

These are sperm producing tubules. Each tubule consists of (a) an outer thin connective tissue coat and (b) a lining of stratified cuboidal epithelium consisting of :

1. Mostly *spermatogenic cells* in different stage of development, and
2. Some *Supporting cells of Sertoli*.

1. Spermatogenic Cells

Arranged in concentric layers (5 or 6) and differentiate progressively from the periphery to the lumen of the tubule. Four successive stages are recognised : *Spermatogonia, primary spermatocytes, secondary spermatocytes* and *spermatids*.

Spermatogonia are mother cells derived from *primordial germ cells* which arise from extraembryonic part of yolk sac. These form an outer layer of cuboidal cells with small nuclei and rest on the basal lamina between the bases of Sertoli cells. These divide to form two types of spermatogonia, type A and type B. The type A spermatogonia are stem cells and produce a proportion of type

A and type B spermatogonia. *Only type B spermatogonia divide into primary spermatocytes.*

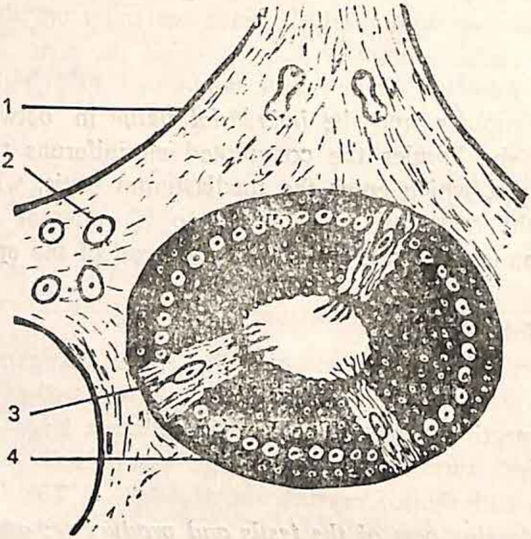


Fig. 71. Section of Testes, 1. Fibrous sheath, 2. Interstitial cells of Leydig, 3. Sertoli cells with spermatozoa on its luminal surface, 4. Spermatogenic cells.

Primary spermatocytes are the largest cells of the series with prominent nuclei. These divide by meiotic division (reduction division) and give rise to haploid secondary spermatocytes.

Secondary spermatocytes are smaller cells with small nuclei and contain half the number of chromosomes. Half of these cells contain 'X' type of sex-chromosomes, and the other half have 'Y' type. Each secondary spermatocyte gives rise to two spermatids.

The *spermatids* are small cells (haploid) with vesicular nuclei, forming several layers bordering the lumen. These become converted into spermatozoa, which for a time remain attached to Sertoli cells.

Spermatogenesis is the process by which spermatogonia are transformed into spermatozoa. It involves two phases : (1) *spermatocytogenesis,* (2) *spermeiogenesis.* Formation of spermatids completes spermatocytogenesis, which is concerned with reduction division. Spermeiogenesis comprises the series of changes in which the spermatid is converted into spermatozoa ; it involves loss of cytoplasm, condensation of the nucleus and formation of a long tail.

Spermatozoon : About 50 μ long ; consists of a head, a neck, a middle piece (body) and a tail.

The oval head consists of the condensed nucleus and is covered on its anterior 2/3 by a bilaminar cap, the *head cap* or *acrosome* derived from Golgi complex. The *neck* is the constricted part and contains two centrioles. The *middle piece* consists of axial filaments surrounded by mitochondrial sheath ; its axial filament consists of 2 circles of nine paired filaments around a central pair. The *tail* is similar to cilia and helps in locomotion.

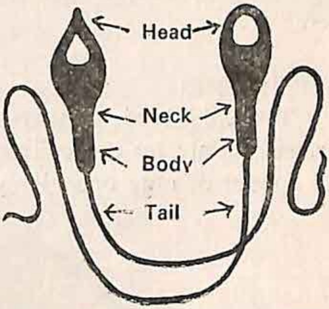


Fig. 72. Two Spermatozoa (edge, face).

A mature sperm contains either 'X' (female determining chromosome), or 'Y' (male determining chromosome) sex-chromosome, and thus it determines the sex of the zygote at fertilization.

2. Supporting Cells of Sertoli

These are tall columnar cells located at fairly regular intervals between the crowded spermatogenic cells. Nucleus is large, oval, vesicular and situated near the base. The bases of Sertoli cells rest on the basal lamina, while the free ends extend towards the lumen, which are profusely branched to which many developing spermatozoa are embedded. The *Sertoli cells provide support and nutrition to the developing spermatozoa.*

Straight Seminiferous Tubules and Rete Testes. Both are lined by a single layer of low cuboidal or flattened cells, and are supported by a little connective tissue.

Pre-pubertal Testis

Before puberty the seminiferous tubules appear as solid cords of epithelial cells without a definite lumen. Supporting cells of Sertoli dominate the field ; some large clear cells are spermatogonia. The stroma between the seminiferous tubules contain groups of undifferentiated interstitial cells, which only begin to secrete at and after puberty under the influence of I C S H.

MALE GENITAL DUCTS

Vasa Efferentia

Surrounded by a thin layer of smooth muscle circularly arranged and lined by simple columnar epithelium, partly ciliated and partly secretory.

EPIDIDYMIS

The epididymis consists of a head, body and tail. The head is formed mainly by the coiling of the efferent ductules. The body and tail consist of only one highly convoluted tubule about 6 metres long.

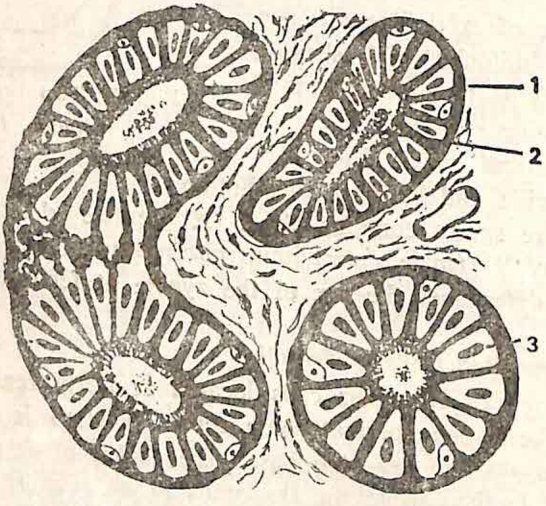


Fig. 73. Section of Epididymis. 1. Smooth muscle, 2. Spermatozoa in lumen, 3. Pseudostratified columnar ciliated epithelium.

In section the tubule (body & tail) is cut many times and in various planes and consists of :

1. A thin layer of smooth muscle arranged circularly.

2. *Lining epithelium* : Pseudostratified columnar ; the free surfaces of tall cells bear **tufts of non-motile** cilia (sterecilia). The lumen contains bunches of spermatozoa. The sperms are stored in the epididymis. Here they get its nutritive secretion and are activated.

VAS DEFERENS

The vas deferens, about 45 cm. long, is the continuation of the tail of epididymis. Its terminal part is dilated to form the *ampulla*. The vas deferens has a thick wall but a small lumen and feels cord like.

1. *Outer fibrous coat*: Thin and blends with the surrounding connective tissue.

2. *Middle muscular coat*: Very thick and has three sublayers of smooth muscle: thick outer longitudinal, thick middle circular, and thin inner longitudinal.

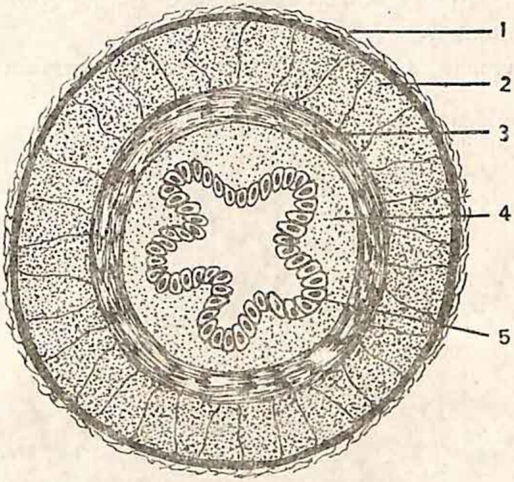


Fig. 74. T.S. of Vas deferens. 1. Fibrous coat, 2. Outer long muscle, 3. Middle circ. muscle, 4. Inner long muscle, 5. Pseudostratified columnar epithelium.

3. *Inner mucous coat*: Shows few folds and is lined by a pseudo-stratified columnar epithelium. Many of the tall cells bear non-motile cilia (stereocilia).

In the ampulla the lumen is large and the mucous membrane has many folds.

Ejaculatory Duct

The ejaculatory duct, about 2 cm. long, is supported by fibrous tissue. The muscle coat is thin and merges with the muscles of the prostate. The mucosa has many folds and is lined by pseudo-stratified columnar epithelium; the tall cells are secretory.

ACCESSORY MALE SEX GLANDS

SEMINAL VESICLES

The seminal vesicles are paired *sacculated glands* consisting of :

1. *Outer fibrous coat* : Merges with the surrounding connective tissue.

2. *Middle muscular coat* : An outer longitudinal and an inner circular layers of smooth muscle fibres.

3. *Inner mucous coat* : Shows elaborate branching and anastomosis giving it a honeycombed appearance. Lining epithelium is pseudostratified columnar.

Seminal vesicle is a gland but it does not contain alveoli. The lining cells secrete a yellow viscous fluid, weakly alkaline and forms a large part of seminal fluid. It is not a reservoir for spermatozoa.

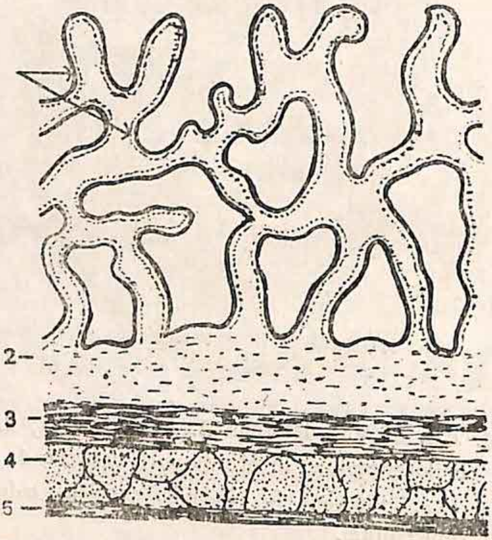


Fig. 75. Section of Seminal vesicle. 1. Mucosal branching and anastomosis, 2. Lamina propria, 3. Inner circ. muscle, 4. Outer long muscle, 5. Fibrous coat.

PROSTATE

The prostate gland surrounds the prostatic urethra. It is composed of about 30 to 50 compound tubulo-alveloar glands arranged in 3 groups : *mucosal, submucosal* and *main prostatic glands.*

A. Stroma (*Connective tissue framework*)

1. *Fibromuscular capsule* : Enclosing the whole gland. There is a false capsule superficial to it derived from pelvic fascia.

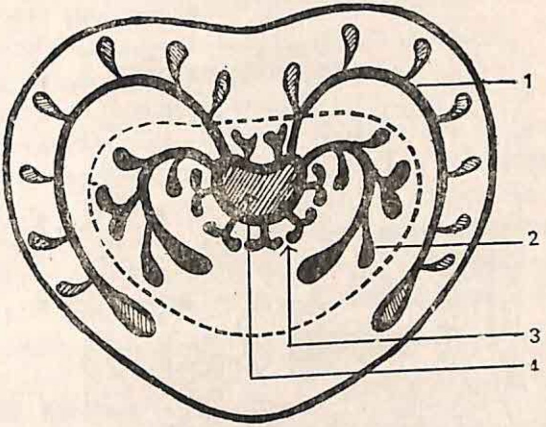


Fig. 76. Cross section of Prostate. 1. Outer main gland (carcinomatous zone), 2. Middle submucosal glands (Adenomatous zone), 3. Mucosal glands, 4. Urethra

2. *Fibromuscular septa* : Pass inside and subdivide the gland into rather indistinct lobules. The septa are continuous with similar stroma (interfollicular tissue) in which the follicles are embedded.

B. Parenchyma

The parenchyma consists of large numbers of branching tubules with dilated ends. In section they appear as follicles of different shapes and sizes, and are lined by pseudostratified columnar epithelium. The epithelium is usually thrown into folds which are supported by thin extensions from fibromuscular tissue.

C. Secretion

Prostatic secretion is granular and acidophilic ; often the lumen contains small colloid bodies termed amyloid bodies (*corpora amylacea*), which are secretion condensation and concentrically lamellated. The secretion is thin milky and slightly *alkaline* and forms a large part of seminal fluid. It contains acid phosphatase, prostaglandins besides citric acid, amylases, proteases and fibrinolysin. Prostaglandins stimulates smooth muscles of female genital tract.

D. Prostatic Utricle

It is a blind sac located within the posterior part of prostate and opens on the colliculus seminalis of the prostatic urethra. The epithelium is similar prostate.

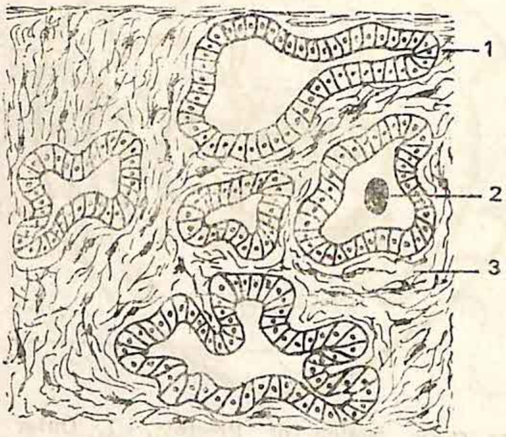


Fig. 77. Section of Prostate (H.P.). 1. Follicle, 2. Amyloid body, 3. Fibro-muscular stroma.

E. Age changes

At birth: Prostate consists of duct system embedded in a fibromuscular stroma. There are no follicles, they are simply represented by end buds on the ducts.

Till puberty: Slow but continuous increase in the size of the prostate.

At puberty: Rapid increase in size (twice) due to formation of follicles under the influence of male sex hormone.

During 3rd decade: Infoldings of the epithelium appear in the follicles.

After 3rd decade: Infoldings decrease, but amyloid bodies increase both in size and number.

The size of the prostate remains constant till 45 years of age, after which it undergoes benign hypertrophy (involves the submucosal glands mainly) or progressive atrophy.

Bulbourethral Glands

Compound tubulo-alveolar glands lined by cuboidal to columnar cells ; secrete a mucoid substance rich in sialo-protein.

PENIS

The penis consists of 3 cylindrical masses of erectile tissue : the paired corpora cavernosa, and a single corpus spongiosum which distally expands into *glans*. The erectile tissue consists of a spongework of fibro-muscular trabeculae, and a system of endothelial lined spaces between them, the so called blood sinuses.

The glans penis contains modified sebaceous glands (of Tyson) which secrete *smegma*. The corpora cavernosa are surrounded by a dense fibro-elastic sheath (tunica albuginea) but separated by an incomplete septum. The sheath enclosing the corpus spongiosum is thinner and more elastic. A common connective tissue sheath encloses the three cylinders together. The skin in thin ; anteriorly it forms a free fold, the *prepuce* which covers the glans. The penis is well supplied with afferent nerve endings.

Mechanism of Erection

Erection of the penis is a purely vascular phenomena ; the deep arteries of the penis take an active part in it. It runs lengthwise in the trabeculae of each corpus cavernosum and gives rise to helicine arteries, which run spirally and open directly into the sinuses. Most of the times these arteries are contracted and the sinuses are almost empty. During erection these arteries relax and the cavernous spaces are suddenly filled with blood, which in turn compress the veins under tunica albuginea. Venous return is hampered and the whole organ becomes tense. After ejaculation the helicine arteries contract ; blood supply to the sinuses is shut off and flaccidity is resumed slowly.

Seminal Fluid (Semen)

The seminal fluid consists of spermatozoa suspended in the secretions of several accessory glands, the chief of which are seminal vesicle, prostate and bulbourethral glands. Each ml. of seminal fluid contains about 100 millions of spermatozoa together with some desquamated epithelial cells and lymphocytes. The sperms become actively motile after ejaculation in the female genital tract.

15 Female Reproductive System

The female reproductive system comprises of paired **ovaries,** paired uterine tubes, uterus, vagina and external genitalia.

OVARIES

The ovaries are paired sex glands in the female. From puberty onwards they have two fold functions—*Production of ova and female sex hormones.*

Germinal Epithelium

A single layer of cuboidal cells (modified peritoneum surrounding the ovary.

Connective Tissue Framework

1. *Tunica albuginea* : A capsule of dense collagen fibres enclosing the ovary deep to germinal epithelium.

2. *Ovarian stroma* : Consisting of spindle shaped connective tissue cells (stromal cells) resembling smooth muscle, but lack the fibrils in their cytoplasm and are not contractile.

Parts : Inner medulla and outer cortex.

A. The *Medulla* is the inner part surrounding the hilus. The stroma consists of loose fibroelastic tissue with scattered smooth muscle and many tortuous blood vessels.

B. The *Cortex* is the outer part. The cortical stroma is dense, more cellular but less vascular. It contains : (i) Ovarian follicles in the different stages of development and regression and (ii) Corpus luteum.

Ovarian Follicles

The production of ova by ovary (*oogenesis*) is a cyclic process, which occurs during the fertile life of a women (puberty to menopause). It is characterized by formation, growth and maturation of ovum in a vesicle—the ovarian follicle.

The primordial germ cells arise in early embryo from the yolk sac and migrate to the developing ovary, where they differentiate into *oogonia.* The oogonia divide to form primary oocytes which become surrounded by a single layer of flattened cells and are known as *primordial follicles.*

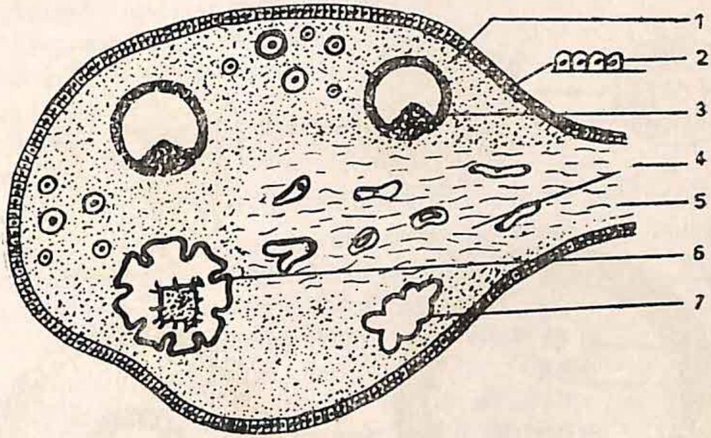


Fig. 78. L.S. of Ovary. 1. Cortex, 2 Germinal epithelium, 3. Vesicular follicle, 4. Medulla, 5. Hilus, 6. Corpus luteum, 7. Corpus albicans.

With the onset of puberty a number of quiescent primordial follicles begin development with each ovarian cycle. The flattened cells surrounding the primary oocyte become cuboidal and are called *follicular* cells. The follicle is now termed *primary follicle.* Now the follicular cells multiply and become many layered (*secondary follicle*). At this time a transparent homogeneous membrane develops around the primary oocyte. This is *zona pellucida* which is formed probably by both the oocyte and the innermost follicular cells. It helps in the nutrition of ovum and later prevents its too early embedding.

The follicular cells are also called granulosa cells. Now a fluid filled cavity appears amongst the granulosa cells (*vesicular ovarian follicle*). The fluid is *liquor folliculi* and the cavity *antrum folliculi.* This cavity divides the granulosa cells into two parts—an outer layer, the *membrana granulosa,* and an inner layer surrounding the ovum, the *cumulus oophorus.* At one point both the layers are in contact termed the *discus proligerus*. The developing follicle becomes surrounded by the theca folliculi derived from the stromal cells of the ovary. The theca folliculi has two layers : (a) an inner vascular and more cellular, the *theca interna* and (b) an outer dense and fibrous, the *theca externa*. A mature follicle ((*Graafian follicle*) takes about 10 to 14 days to complete its development.

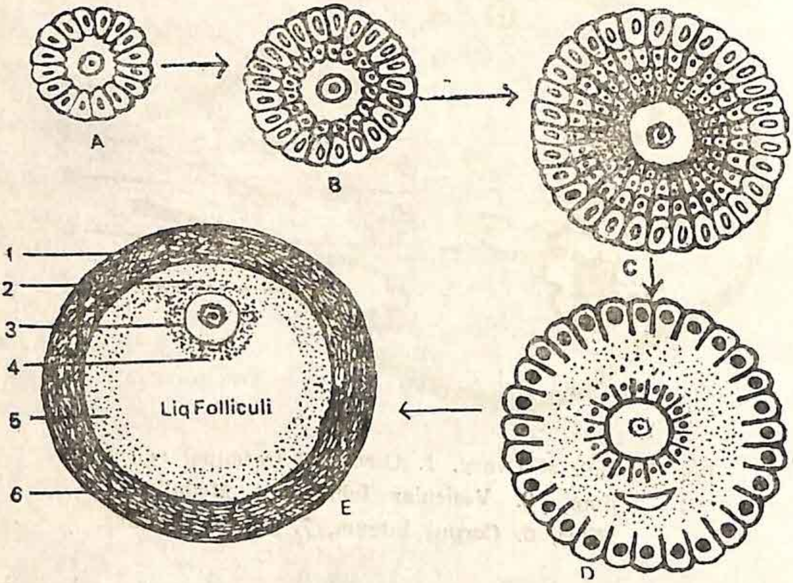


Fig. 79. Stages in the development of Graafian follicle. A. Primary follicle, B & C. Secondary follicles, **D. Vesicular follicle, E. Graafian follicle. 1. Theca extena, 2. Discus proligerus.** 3. Ovum, 4. Cumulus oophorus, 5. Membrana granulosa, **6. Theca interna.**

While the above changes are taking place in the follicular cells, the primary oocyte increases in size. Then the 1st meiotic division takes place, which results in two unequal cells—one large containing the bulk of cytoplasm, the *secondary oocyte*, and the other small, the *1st polar body*, which lies between the zona pellucida and the cell membrane of the secondary oocyte. Both these cells contain half the number of chromosomes. The secondary oocyte, now prepares for the 2nd meiotic division, and at this stage the ovum is liberated from the ovary. It must be emphasized that the 2nd meiotic division is completed in the uterine tube, only after fertilization has taken place.

Mature ovum

Size : 117μ to 142μ in diameter.

Nucleus (germinal vesicle) : Large, vesicular with a prominent nucleolus (*germinal spot*).

Cytoplasm (yolk) : Granular.

Cell membrane (vitelline membrane). Thin and surrounded by zona pellucida.

Ovulation

The process of liberation of mature ovum by the rupture of ovarian follicle into the peritoneal cavity is termed ovulation. It occurs approximately every 28 days in a non-pregnant sexually mature woman, about 14 days before the onset of menstruation. The ovum surrounded by cumulus oophorus, now called *corona radiata* bursts through the surface of the ovary. As a rule one ovum is released at a time, and the ovaries usaully alternate. The liberated ovum is picked up by the fimbriated end of the uterine tube.

Corpus Luteum

Following ovulation, the ruptured follicle collapses and the membrana granulosa becomes folded. This is corpus luteum, an endocrine gland. Under the influence of L H the granulosa cells enlarge greatly and acquire lipid droplets in their cytoplasm—*granulosa lutein cells* (luteal cells) which secrete progesterone. Theca interna forms *theca lutein cells* (Para luteal cells) which secrete oestrogen. The theca externa remains unchanged and forms a fibrous capsule to the developing corpus luteum.

Types

1. *Corpus luteum of menstruation,* if fertilization does not occur.
2. *Corpus luteum of pregnancy* when pregnancy ensues.

The two differ mainly in size and duration. The corpus luteum of menstruation is a transient structure. It has a life of about 14 days after which the lutein cells undergo fatty degeneration and are replaced by fibrous tissue (corpus albicans). The corpus luteum of pregnancy is very large, the size may reach to about 2.5 cm. or more. It continues to grow until about the 5th month of pregnancy, and then begins to degenerate and finally a large corups albicans is formed.

Atresia (degeneration) of Follicles

Atresia is the fate of most follicles. At birth, each human ovary contains about 100 thousands or more primordial follicles. After puberty a number of follicles grow in each cycle, but only one wins the ovulatory race, the rest become atretic. Thus only about 400 follicles reach full maturity during the 30 years of active sexual span. All unsuccessful follicles involute (degenerate). Atresia of a follicle involves first a degeneration of ovum followed by the follicular cells.

Interstitial cells

Interstitial cells are groups of epitheloid cells in the ovarian stroma, mainly derived from the theca interna of atretic follicles and are most abundant during the first year of life, when atresia of the follicles are common. In adult human ovary they are poorly developed.

UTERINE TUBE

The uterine tube, is a muscular tube, which receives and transports ovum to the uterus. It is about 10 cm. long and has 4 parts—infundibulum, ampulla, isthmus and the intramural part. Fertilization takes place in the lateral third (ampulla) of the uterine tube.

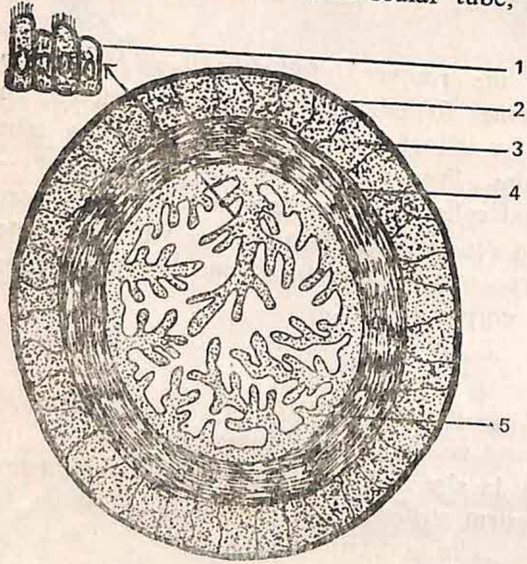


Fig. 80. Uterine tube (cross). 1. Simple columnar epithelium partly ciliated, 2. Serous coat, 3. Outer long. muscle, 4. Inner circ. muscle, 5. Mucous coat.

The uterine tube has three coats :

1. *Outer serous coat* : Continuous with the peritoneum of broad ligament.

2. *Middle muscular coat* : Consists of two subalyers of smooth muscle—thin outer longitudinal, thick inner circular.

3. *Inner mucous coat* : Shows large number of folds with primary, secondary and tertiary branching but no anastomosis. The *lining epithelium* is simple columnar, partly ciliated and partly secretory. The lamina propria is very cellular.

THE UTERUS

The uterus is a hollow pear shaped muscular organ. It is about 3″ × 2″ × 1″ and has a *fundus*, a *body* and a *cervix*. The *isthmus* is the transitional zone between the body and the cervix. The uterus has three coats :

1. *Outer serous coat* (*Perimetrium*) : Continuous with the peritoneum of broad ligament.

2. *Middle muscular coat* (*Myometrium*) : Very thick (1.25 cm.) ; bundles of smooth muscle are arranged in 3 ill-defined sublayers—outer thin longitudinal ; middle thick mainly circular with few oblique fibres ; inner thin layer contains both longitudinal and circular fibres. In pregnancy, the muscle fibres increase considerably both in size (hypertrophy) and number (hyperplasia).

In cervix most of the muscle bundles are circularly arranged and separated by abundance of collagen and elastic fibres giving it a firm consistency.

3. *Inner mucous coat* (*Endometrium*) : Lined by simple columnar epithelium—partly ciliated, partly secretory. Lamina propria is very cellular and contains many stromal cells. Simple tubular glands extend through the full thickness of the mucosa ; at the basal ends the glands may branch. These glands are lined by columnar cells, some of which are ciliated.

In the cervix the mucosa is thick and the surface cells are taller. Cervical glands are lined by high columnar cells and secrete mucus. The lamina propria is more fibrous and less cellular. Cervical glands are much branched.

Arterial supply

Two types of arteries supply the endometrium. The *basal arteries* are straight and supply the basal 1/3 only. The *spiral arteries* pursue a tortuous course through the deeper parts of the endometrium and break up into a dense capillary network beneath the uterine epithelium. They supply functional zone i.e., stratum compactum and stratum spongiosum, and take part in menstruation.

Uterine (Menstrual) Cycle (Fig. 81)

The series of changes that occur in the uterus for the possible implantation of a fertilized ovum is called uterine cycle. The changes involve chiefly the endometrium of the fundus and the body, the cervix is spared. This cycle occurs during the fertile life (usually 15 to 45 years) of a woman, but are absent during pregnancy and lactation. The first day of menstrual flow is taken to be the 1st day of the cycle.

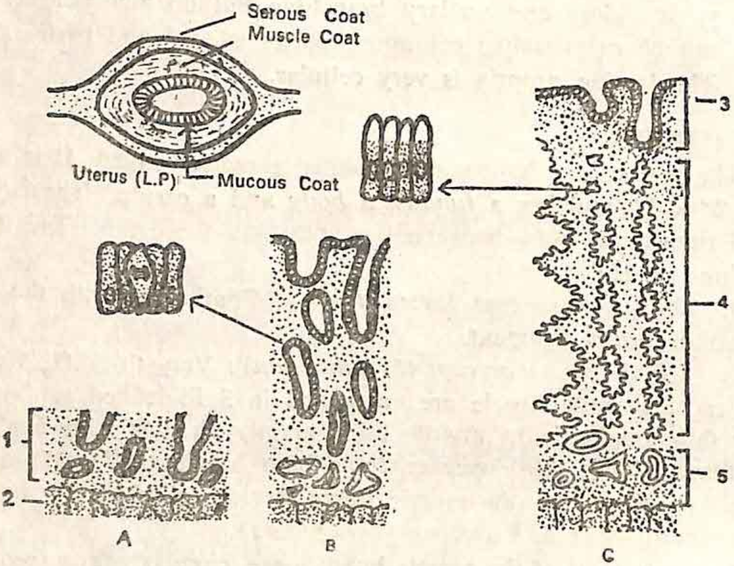


Fig. 81. Uterus, A. B. C. Cyclic stages in uterine mucosa. A.-Mucosa at the end of menstruation. B-Proliferative phase, C.-Secretory phase. 1. Denuded mucosa, 2. Muscle coat, 3. Stratum compactum. 4. Startum spongiosum, 5. Stratum Basilis.

Phases: Menstrual, Follicular (proliferative), and Luteal (secretory).

Menstrual phase (1st—4th day): The spiral arteries constrict intermittently, leading to necrosis of the functional zone which is shed piecemeal ; only the basal part containing basal parts of the glands are left. *The endometrium just after menstrual phase is only 0.5 mm. thick.*

Follicular phase (5th—14th day) : The lost epithelium is regenerated from the mouths of torn glands. By the end of this phase the endometrium becomes 2 to 3 mm. thick. Ovulation normally occurs at the end of this phase.

Luteal phase (15th—28th day) : The endometrium thickens ; by the end of this phase it becomes 5 to 7 mm. and is divisible into 3 zones : superficial stratum compactum, middle stratum spongiosum and a deep stratum basilis. The glands becomes dilated and tortuous ; in longitudinal section they give a saw-toothed appearance.

Changes During Pregnancy

The endometrium of pregnant uterus is called *decidua.* Secretory phase continues ; stromal cells change into *decidual cells,* which are large epithelial cells with granular cytoplasm. The glands elongate and become more tortuous. The whole uterus including blood vessels increase enormously.

Placenta : Decidua basilis forms the maternal part of placenta, the major part being formed the foetal tissue composed of chorionic villi which lie in a lake of maternal blood. The chorionic villi consist of a central core of mesenchyme containing foetal blood vessels and is covered by trophoblast (outer syncitio - and inner cyto-trophoblast). It secretes oestrogen, progesterone and chorionic gonadotrophins.

The placenta is covered on its foetal aspect by simple cuboidal epithelium of the amnion ; which is reflected on the outer surface of the *umbilical cord.*

(*Umbilical cord* : Wharton's jelly forms its central core in which lies paired umbilical arteries and left umbilical vein).

Changes After Parturition

The endometrium is repaired in the same way as in the follicular phase. All other elements return to their normal size.

Changes After Menopause

After menopause the endometrium becomes very thin and atrophic.

Hormonal Control of Ovarian & Uterine Cycles

During the first half of each menstrual cycle, the anterior lobe of pituitary gland produces follicular stimulating hormone (F.S.H.) which stimulates the ovarian follicles to develop. At this stage the ovaries secrete oestrogen, which initiates and regulates the proliferative phase of the uterine endometrium. At mid-cycle the anterior pituitary begins to secrete LH, which brings about ovulation, and thereafter controls the formation and maintenance of corpus luteum. The corpus luteum, in turn produces progesterone, and the theca interna continues to produce oestrogen. The combined action of these two hormones produces the secretory changes in the endometrium, which is an essential preparation for the reception of fertilized ovum and its nourishment.

Should fertilization take place, the corups luteum continues to increase in size until about 5th month of pregnancy, after which it starts to degenerate as the production of progesterone and oestrogen is taken over by the placenta. If fertilization does not occur, corpus luteum degenerates, progesterone secretion stops and the uterine mucosa breaks down at menstruation.

VAGINA

The vagina is an elastic fibromuscular tube consisting of three layers :

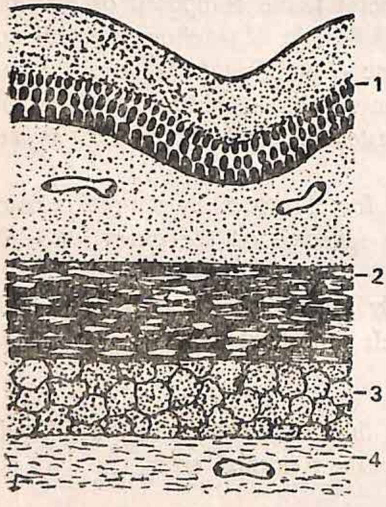


Fig. 82. Vagina (cross). 1. Str sq. epith. (N.K.), 2. Inner circ. muscle, 3. Outer long. muscle, 4. Fibrous coat.

1. *Outer thin fibrous coat* : Merges with surrounding connective tissue.

2. *Middle muscular coat* : Consists of smooth muscle in two sublayers—outer thick longitudinal, inner thin circular. At the lower end of vagina there is a sphincter of skeletal muscle.

3. *Inner mucous coat*: Thrown into longitudinal folds; lining epithelium is stratified squamous non-keratinised. Glands absent, the epithelium is lubricated by the mucus of cervical glands. Also muscularis mucosae is absent (cf. oesophagus).

Hymen consists of a thin connective tissue core lined by stratified squamous epithelium on both surfaces.

External Genitalia

Clitoris: Consists of two small masses of erectile tissue ending in a small glans, and corresponds to the dorsal part of penis.

Labia Minora: Two thin folds of mucous membrane lined by stratified squamous epithelium (non-keratinized) and contain a central core of vascular connective tissue. Hairs are absent, but large sebaceous glands present on both surfaces.

Vestibular Glands: (a) *Small vestibular glands* are mucous glands located around the urethral opening (homologue to urethral glands of Littre of male).

(b) *Greater vestibular glands* (*Bartholin's gland*): Tubulo-alveolar glands; secrete mucus (homologue to the male bulbourethral glands).

Labia Majora: Two *folds of skin.* Inner surface hairless.

16 Special Sense Organs

THE EYE BALL

Coats of eye ball :

1. Outer fibrous coat : **Cornea, Sclera.**
2. Middle vascular coat (uveal tract) : Choroid, Ciliary body, **Iris.**
3. Inner nervous coat : **Retina.**

CORNEA

Cornea is transparent and has 5 layers.

1. *Corneal epithelium* : Thin stratified squamous epithelium non-keratinized, consisting of 5 layers of cells.

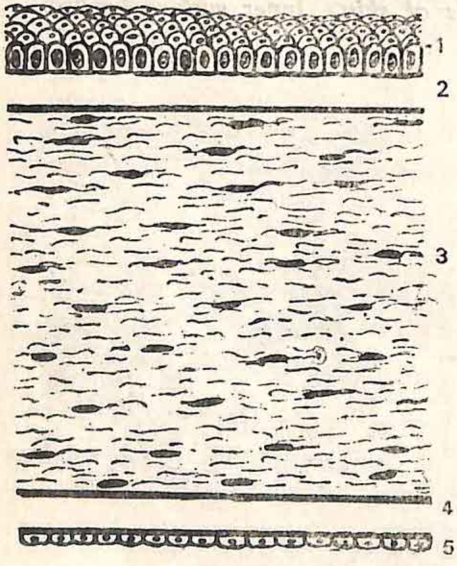


Fig. 83. Secion of cornea. 1. Str. sq. epith. (N.K.), 2. Anterior elastic lamina, 3. Substantia propria, 4. Posterior elastic lamina, 5. Mesothelium of anterior chamber.

2. *Anterior elastic lamina* (Bowman's membrane) : Thin transparent homogeneous membrane.

3. *Substantia propria* : Forms the main part of cornea and is

composed of collagen bundles in layers. Corneal corpuscles (cells with branched processes) lie in the spaces between the layers.

4. *Posterior elastic lamina* (Descemet's membrane) : Thin transparent homogeneous membrane. At the corneo-scleral junction the posterior elastic lamina breaks up into bundles of fine interlacing fibres ; the spaces between the bundles form *spaces of iridocorneal angle* (of Fontana). The bundles then unite to form *pectinate ligament* connecting the sclera with the root of iris.

5. *Mesothelium of anterior chamber* : A single layer of flat cells.

Sclera

Sclera is tough and opaque, and is composed of dense collagen bundles with some elastic fibres. At the corneo-scleral junction, there is a circumferential canal termed *canal of Schlemm.*

Choroid

The choroid is mainly composed of blood vessels consisting of outer pigmented layer, middle vascular layer, and inner transparent basal lamina.

Ciliary Body

Structure similar to choroid but has extensive capillary network. Besides, it contains, the *ciliary muscle.* The ciliary processes secrete aqueous humor into the posterior chamber.

Iris

Iris has three layers :

1. A layer of flattened mesothelial cells anteriorly.
2. Intermediate delicate connective tissue stroma containing blood vessels, nerves, pigment cells and two groups of smooth muscle, the sphincter and dilator pupillae. Both the muscles are ectodermal derived from optic cup.
3. Posteriorly iridal part of retina containing two layers of columnar cells.

RETINA

Parts :

(A) **Optic part :** From optic disc to ora serrata, including optic disc and macula lutea.

(B) **Non-nervous ciliary and iridal part.**

Structure of optic part :

The retina consists of 3 layers of neurons, their nuclei, processes and synapses. It has 10 layers :

1. *Outer pigment layer* consisting of a single layer of cuboidal cells. Each cell covers about 10 rods and cones. It reduces the scattering of light within the eye.

2. *Layers of rods and cones* are modified dendrites of outer nuclear layer. They have outer and inner segments joined together by axial filaments. Outer rod segment is long and thin, and contains *rhodopsin* (visual purple) ; outer cone segment is thick and conical and contains *iodopsin* ; the outer segment of both rods and cones contains stacks of flattened saccules.

Number : Rods—125 millions, absent over fovea centralis and optic dics. Cones—7 millions, absent over optic disc. only cells at fovea centralis, elsewhere their distribution is fairly even.

Functions : Rods and cones initiate visual impulse. Rods react to low intensity illumination and subserve night vision. Cones react to high intensity illumination and subserve colour vision and acuity of vision.

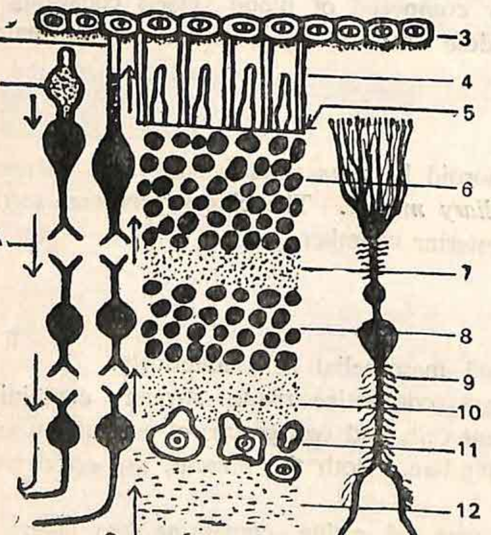


Fig. 84. Section of Retina. 1. Rod cell, 2. Cone cell, 3. Outer pigmented layer, 4. Layer of rods and cones. 5. Outer limiting membrane, 6. Outer nuclear layer, 7. Outer plexiform layer, 8. Inner nuclear layer, 9. Supporting cell of Muller, 10. Inner plexiform layer, 11. Ganglion cell layer, 12. Stratum opticum, 13. Internal limiting membrane. A. Pathway of nerve impulse. B. Pathway of light rays.

3. *Outer limiting membrane* formed by the meeting of the outer ends of Muller cells (modified neuroglial cells).

4. *Outer nuclear layer* contains cell bodies of rods and cones.

5. *Outer plexiform layer* is the first synaptic layer between the central processes of rod and cone cells with the dendrites of inner nuclear layer.

6. *Inner nuclear layer* contains cell bodies of bipolar cells. Besides, this layer contains horizontal and amacrine cells, and supporting cells of Muller.

7. *Inner plexiform layer* is second synaptic layer between the axons of bipolar cells and the dendrites of multipolar ganglionic cells.

8. *Ganglionic cell layer* contains a single layer of large multipolar cells ; at macula lutea they form several layers.

9. *Stratum opticum* is formed by the axons of ganglionic cell layer and is continued as optic nerve, which is a fibre tract of CNS and not a peripheral nerve.

10. *Internal limiting membrane* formed by the inner ends of the supporting cells.

Macula Lutea is an oval yellowish area, 1 to 2 mm. in diameter near the centre of the posterior pole of retina. Fovea centralis is the depression (about 0.5 mm. diameter) in its centre, where only cones are present. Fovea centralis is the area of most distinct vision.

Optic Disc is the area, about 1.5 mm. in diameter, where the fibres of stratum opticum converge and the optic nerve leaves. It is situated about 3 mm. to the nasal side of macula lutea. Rods and cones are absent here, so the optic disc is insensitive to light and is termed the '*blind spot*'.

Ciliary and Iridal parts of Retina :

In ciliary part there are two layers of tall columnar cells, the deeper layer is pigmented, whereas in iridal part both layers are heavily pigmented.

REFRACTIVE MEDIA OF THE EYE

Cornea (most important refractive media), aqueous humor, lens and vitreous humor.

Aqueous Humor

Aqueous humor is a clear transparent fluid secreted mostly by the ciliary processes into the posterior chamber. It passes to the anterior chamber through the pupil and then through the spaces of iridocorneal angle to the sinus venosus sclerae (canal of Schlemm), which in turn ends in the anterior ciliary veins.

Vitreous Humor

The vitreous humor is a transparent jelly like semisolid mass behind the lens. Its peripheral part forms the hyaloid membrane which thickens near the ciliary body to form the ciliary zonule and is attached to the ciliary processes. The ciliary zonule breaks to form the suspensory ligament of the lens which is attached to the periphery of the lens.

Lens

The lens is a transparent, colourless plastic and biconvex disc. It has (i) transparent elastic capsule, (ii) columnar epithelium deep to capsule on the anterior surface only, and (iii) substance of the lens, made up of lens fibres and consists of a firm central part the *nucleus* and the outer soft part of the *cortex.*

The function of lens is to focus the rays of light on the retina.

EYE LIDS

Each eye lid consists of a central plate of dense connective tissue called the *tarsal plate* and is covered with skin on the outside and the *conjunctiva* on the inside. Two to three rows of eye lashes are present on the free margin. The *ciliary glands of Moll* open either in the follicles of the eye-lashes or between them. Numerous *tarsal glands* (modified sebaceous glands) are embedded in the deep surface of tarsal plate and open on the lid-margin behind the eye lashes. The superficial surface of the tarsal plates are covered by orbicularis oculi ; besides smooth muscle (Horner's muscle) is attached to upper tarsus.

The conjunctiva is lined by stratified columnar epithelium.

LACRIMAL GLAND

It is compound tubulo-alveolar gland. Alveoli are lined by cuboidal serous cells with basal myoepithelial cells. The cytoplasm contains large secretion granules.

Lacrimal canaliculi, lacrimal sac and *naso-lacrimal duct* are lined by stratified squamous epithelium.

THE EAR

A. External Ear

Auricle : Consists of irregular plate of elastic cartilage covered by skin on both surfaces.

External acoustic meatus :

(a) Cartilaginous part : Elastic cartilage lined by thick skin containing hairs, large sebaceous glands and modified apocrine sweat glands (ceruminous glands).

(b) Bony part has thin skin ; hairs and glands are absent.

Tympanic membrane : Composed of three layers :

(i) Outer surface lined by thin skin but hairs and glands are absent.

(ii) Middle fibrous layer consisting mostly of collagen fibres ; fibres are absent from pars flaccida.

(iii) Inner mucous layer lined by single layer of low cuboidal or squamous cells.

B. Middle Ear

Lined by simple low cuboidal epithelium.

Pharyngotympanic tube : (a) Bony part lined by simple columnar ciliated epithelium, (b) Cartilaginous part by pseudo-stratified columnar ciliated epithelium.

C. Internal Ear

Utricle, saccule and semicircular ducts :

All are lined by simple squamous epithelium except the ampullary crests and the maculae of utricle and saccule, which are sensory epithelia consisting of *hair cells* and *supporting cells.*

Hair cells are of two types ; many hairs (modified microvilli) project from the free surfaces of both cell types and receive vibratory sense. The supporting cells are fusiform in shape, extend from the basal lamina to the free surface of hair cells ; their free surfaces unite to form a thin cuticle.

In ampullary crests, the hairs are covered by a dome-shaped gelatinous mass (*cupula*).

In maculae, the gelatinous mass covering the hairs is flat called *Otolithic membrane* which contains small crystals of calcium carbonate called *otoliths* (otoconia).

Cochlea

The *outer wall* of cochlear duct is very vascular stratified epithelium termed stria vascularis which secretes endolymph.

The *roof* formed by *vestibular membrane,* consists of a connective tissue sheet covered by a single layer of flat cells on both sides.

The *floor* is formed by *basilar membrane* consisting of modified collagen fibres. The surface facing scala tympani is covered by a single layer of flat cells ; the cochlear side of the membrane supports the spiral organ of Corti.

Organ of Corti consists of *Rods of Corti, hair cells* and various *supporting cells.*

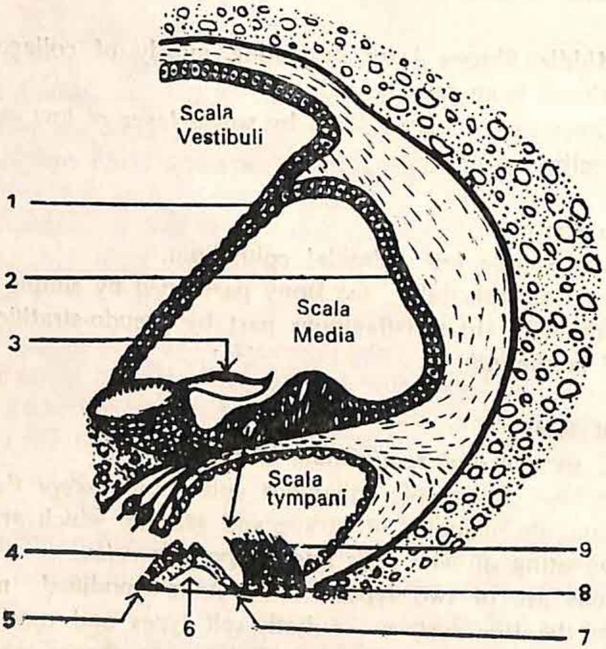


Fig. 85. Section of Cochlea with organ of Corti (enlarged) at the base. 1. Vestibular membrane, 2. Stria vascularis, 3. Tectorial membrane, 4. Inner hair cell, 5. Inner rod of Corti, 6. Tunnel of Corti, 7. Outer rod of Corti, 8. Supporting cells, 9. Outer hair cells.

1. *Rods of Corti* : Comprises of *inner* and *outer* rods. Each rod has a base, body and head. The two rods are separated at their bases, where they are attached to the basilar membrane, but meet at the heads thus enclosing the *tunnel of Corti.*

2. ***Hair cells*** are short columnar cells forming a single row on the inner aspect of inner rods, but 3 or 4 rows on the outer aspect

of outer rods. Their bases do not reach the basilar membrane but are supported by the so called phalangeal cells and are fed by the cochlear nerve; their free surface bear a number of hair filaments (actually microvilli).

3. *Supporting cells*: The phalangeal cells (of Dieter) support the hair cells, one for one. Other supporting cells are cells of Hensen and broder cells.

The tectorial membrane is a thin cuticle which projects laterally from the vestibular lip of the limbus and covers the hair cells of the organ of Corti.

ORGAN OF SMELL (see Nasal cavity).
ORGAN OF TASTE (see Tongue).

17

Identification of Slides

A slide must first be examined under low-power magnification. By this process most of the slides will be identified ; only some will require examination under high power, which is used mainly for the study of minute details.

Also note, that some are *tubular organs* and exhibit a lumen in section : they are—arteries & veins, trachea & bronchi, major part of digestive tube, urinary system except kidney, and male & female genital duct systems. Most of the remaining organs are usually *solid non-tubular organs.* They include lymphoid organs, glands (endocrine & exocrine), lung, epiglottis, tongue, cornea & retina, skin and parts of central nervous system.

Most organs consist of an arrangement of epithelium, connective tissue and smooth muscle with a supply of vessels and nerves. Of these the *epithelium is the most important in identification of slides.*

Epithelium (Figs. 5 & 6)

Epithelium is identified by their appearance in vertical section, and the shape, size and position of nuclei.

Simple epithelium (cells in one layer) ; the nuclei are arranged in a single row. The subtypes are determined by the shape and size of individual cells and the position of the nuclei.

Simple squamous epithelium look like thin plates and the nucleus produces a bulge in the centre of the cell ; *Simple cuboidal epithelium* appears as a row of squares with central nuclei ; *Simple columnar epithelium* appears as a row of rectangles with the nuclei situated at the same level (central or near the base) ; *Ciliated epithelium* bear cilia on their free surfaces ; in *pseudo-stratified columnar ciliated epithelium* the nuclei appear at different levels but are mainly confined to the basal half or two-thirds, and the free surfaces of tall cells bear cilia.

Stratified epithelium (cells in many layers) : The shape of surface cells classifies the subtypes. In most cases the cell outlines are not seen. The shape, size and direction of the nuclei help in identification. In *Stratified Squamous Non-keratinised* the nuclei are in many layers (say 10 or 12). The nuclei of the basal cells are oval and their long axes lie at right angles to basal lamina; the nuclei of intermediate cells are smaller and circular, whereas nuclei near the surface are flattened and lie parallel to the surface. In *keratinised* variety besides the above findings, the superficial dead scales of keratin takes an acidophilic staining. In *transitional epithelium* (4 to 6 layers): In relaxed condition the surface cells are balloon shaped with large spherical nuclei, other cells are polygonal.

Fatty Tissue

In ordinary preparations fat is dissolved out, and the cells appear in the form of large irregular rings each having a dark flat nucleus at one side. The whole tissue appears net-like with empty spaces.

Cartilage (Figs. 13, 14 and 15)

Encapsulated cartilage cells are characteristic. In *hyaline cartilage* the ground substance is homogeneous (glass-like); in *elastic cartilage* the ground substance contains network of elastic fibres, whereas in *fibro-cartilage* it contains bundles of collagen fibres.

Bone (Fig. 16)

Compact bone is identified by Haversian system containing Haversian canal in its centre, concentrically arranged lamellae, with lacunae containing osteocytes.

Bone Marrow

Red marrow is very cellular and contains marrow cells i.e., all stages in the development of RBC, WBC and platelets. Dilated blood vessels (sinusoids) and some bony spicules are present.

Yellow marrow consists mainly of fat cells.

Muscle (Figs. 19, 20, 21 and 22)

Skeletal muscle: In L. S. shows prominent transverse striations having many nuclei located at the periphery. In T. S. nuclei peripheral and *Cohnheim's* areas seen.

Cardiac muscle: Fibres branch and anastomose with one another forming a pseudo-syncytium. As such little spaces are seen in the network of muscle fibres. *Transverse* striations faint; single central nucleus.

Smooth muscle: Stain deeper with eosin than connective tissue fibres. In L. S. appear like parallel bands; nucleus present in the centre and often wrinkled. **In T. S. fibres appear from little circles to dots. Only largest circles include a nucleus.**

Nervous Tissue (Figs. 23, 24 & 25)

Neurons are nerve cells with processes. Cell body takes a light stain, the nucleus is large and vesicular. **Nissl's granules may be seen if stained by toluidine blue. Nerve cells in ganglia are surrounded by a capsule of satellite cells. Osmic acid stains myelin black. In L. S. of nerve fibre or in teased preparation nodes of Ranvier seen.** A. T. S. of nerve trunk (stained by osmic acid) shows little black rings of myelin grouped in small funiculi. The colourless central part is due to unstained axon. Nuclei of Schwann cells may be seen outside some rings, and outside it is the endoneurium. The nerve trunk is enclosed by epineurium.

Spinal cord (Fig. 29): **White matter located peripherally;** [illegible] matter central in position and has the form of an H. Central canal lined by ependyma located in the transverse limb. Each half of 'H' has a ventral and dorsal horn containing multipolar nerve cells. ***The ventral horn contains very large nerve cells.***

Cerebellar cortex (Fig. 30): has three layers; the middle layer comprises of a single layer of large flask shaped nerve cells, the Purkinje cells.

Cerebral cortex (Fig. 31): **Composed of several layers of nerve cells, usually six. Pyramidal cells may be seen in 3rd & 5th layers.**

Artery & Vein (Figs. 32, 33 & 34)

Tunica Media is thickest coat in artery.

In **Elastic Artery:** (i) internal elastic lamina not identifiable. (ii) Elastic fibres predominate in tunica media.

In **Muscular Artery:** (i) Internal elastic lamina is very prominent and thrown into wavy folds. (ii) Smooth muscle predominates in tunica media.

In **Vein** (of medium size): Lumen of vein is larger, but wall is thinner than that of accompanying artery. (i) Tunica adventitia is the thickest coat. (ii) Tunica media very thin. (iii) Internal elastic lamina absent.

Capillary : In L.S. it looks like two parallel beaded lines having a rather uniform bore. In T.S. it appears as a small thin ring with or without a nucleus.

Lymphoid Tissue

Lymphoid tissue is identified by huge collection of little blue dots (nuclei of lymphocytes).

Lymph node (Fig. 36) : Differentiated into cortex and medulla : the cortex is dense and shows lymph nodules some having germinal centres.

Spleen (Fig. 37) : has (i) Prominent capsule and trabeculae ; under low power the trabeculae appear as smooth eosinophilic mass, (ii) No differentiation into cortex and medulla, (iii) The white pulp (Malpighian corpuscle) has an eccentric artery termed central artery of the white pulp.

Thymus (Fig. 39) has large number of lobules each having a cortex and a medulla. The cortex is dense but without any nodules. The medulla conains Hassall's corpuscles.

Palatine tonsil (Fig. 40) : The medial surface and the crypts are lined by non-keratinised stratified squamous epithelium, deep to which lie a number of lymph nodules (with germinal centres) embedded in diffuse lymphoid mass.

Skin (Fig. 46)

(i) Edidermis is lined by keratinised stratified squamous epithelium, (ii) Dermis usually contains hair follicles, sebaceous and sweat glands.

Mammary Glands (Fig. 47)

Dense fibro-fatty capsule and septa. In the active gland, lobules are packed with alveoli and lined by cuboidal to columnar epithelium ; ducts are lined by two layers of cuboidal cells. In the resting gland : abundant fibrous tissue, the lobules are made up chiefly of ducts ; only few acini seen.

Pituitary Gland (Fig. 41)

In T. S. Pars distalis, Pars intermedia and Pars nervosa are seen. Pars distalis is very cellular and contains three types of cells—lightly staining chromophobes, red staining acidophils and blue staining basophils. Pars intermedia forms thin sheet of blue staining cells behind the residual intraglandular cleft. Pars nervosa is the small fibrous looking part and takes a light stain, because of many nerve fibres.

Thyroid Gland (Figs. 42 & 43)

Large number of follicles of different shapes & sizes lined by simple cuboidal epithelium and filled with acidophilic colloid with little interfollicular tissue.

Parathyroid Gland (Fig. 44)

Always associated with thwroid gland and contains cords of lightly staining cells, the cells.

Suprarenal (Adrenal) Gland (Fig. 45)

Consists of cortex and medulla. The cortex is arranged in three zones (i) Outer zona glomerulosa (rounded groups of cells), (ii) Middle zona fasciculata (cells in longitudinal columns), (iii) Inner zona reticularis. The medulla shows basophilic staining cells around wide sinusoids.

Epiglottis (Fig. 48)

Consists of central core of elastic cartilage covered with non-keratinised stratified squamous epithelium on both surfaces.

Trachea (Fig. 49)

Outer fibrous coat ; middle coat consisting of 'D' shaped rings of hyaline cartilage, and inner lining of pseudo-stratified columnar ciliated epithelium with intervening goblet cells.

Lungs (Fig. 50)

Different orders of bronchial tree (specially bronchiole and respiratory bronchioles) scattered in a network of empty spaces (alveoli) having thin walls (lined by simple squamous epithelium) broken at many places.

Tongue (Fig. 52)

(1) Skeletal muscles running in different directions, (2) Mucous membrane lined by stratified squamous epithelium ; and some of lingual papillae seen, most common being filiform.

Oesophagus (Fig. 53)

(i) Usual 4 coats of G.I.T. (ii) Lining epithelium stratified squamous non-keratinised ; presence of prominent muscularis mucosae differentiates it from vagina.

Stomach (Fundic Part) (Fig 54)

(i) Usual 4 coats of G.I.T. (ii) No villi ; lining epithelium simple columnar without goblet cells. (iii) The fundic glands are fairly straight tubes with narrow lumen containing 3 types of cells ; red staining oxyntic cells, blue staining peptic cells and lightly staining mucous cells ; the gastric pits (ducts) are much shorter.

Stomach (Pyloric part)

The gastric pits (ducts) are much longer while the secreting tubules are shorter, and contain only lightly staining mucoid cells. Also the muscle coat is thicker.

Small Intestine

(i) Usually 4 coats of G.I.T. and characterised by presence of villi. Goblet cells seen.

The *duodenum* (Fig. 55) contains submucosal glands of Brunner. The *jejunum* is devoid of submucosal glands and Peyer's patches. The *ileum* (Fig. 56) has Peyer's patches (aggregated lymph nodules) in the mucous coat which extends into the submucous coat.

Large Intestine

Colon and caecum (Fig. 57) : Absence of villi, closely packed simple tubular glands with numerous goblet cells.

Appendix (Fig. 58) : (i) Wall much thicker compared to the lumen, (2) Intestinal glands less in number than in colon, (3) Numerous lymph nodules in the mucous coat extending into submucous coat and forming a sort of lymphoid ring, (4) muscularis mucosae deficient.

Salivary Glands (Figs. 59 & 60)

Parotid gland : (i) Only serous alveoli. (ii) Ducts are profuse and prominent,

Submandibular gland : (i) Both serous and mucous alveoli with serous crescents. (ii) Dusts similar to parotid gland.

Pancreas (Fig. 61)

(i) Only serous alveoli—the serous cells exhibit acidophilic apices and basophilic bases. (ii) Ducts are few. (iii) Islets of Langerhans seen.

Liver (Fig. 62)

Large number of hexagonal hepatic lobules containing a central vein (not collapsed) in its centre. (ii) Radiating cords of liver cells one cell thick from centre to periphery. (iii) Portal canal at the edges of hepatic lobules—**comprising a branch of portal** vein and hepatic **artery and an interlobular bile ductule.**

Gall Bladder (Fig. 64)

(i) Outer fibrous coat, (ii) Middle fibromuscular coat, (iii) Mucous coat shows branching and anastomoses giving a honeycombed appearance. Lining epithelium—single layer of tall columnar cells. No muscularis mucosae.

Kidney (Figs. 66 & 67)

Identified by renal corpuscles in the cortex.

Ureter (Fig. 68)

Section of very small size and lumen star shaped ; lining epithelium—transitional.

Urinary Bladder (Fig. 69)

Lumen irregular or only part of the organ seen ; muscular coat is thick ; mucosa has many folds ; lining epithelium transitional.

Testis (Fig. 71)

Seminiferous tubules in section show multiple shapes & sizes and are lined by stratified cuboidal epithelium. Some sperms may be seen in the lumen. Interstitial cells of Leydig present between the seminiferous tubules.

Epididymis (Fig. 73)

Lined by pseudostratified columnar epithelium having prominent non-motile cilia. Lumen usually contain bunches of sperms.

Vas Deferens (Fig. 74)

Section of very small size, very thick wall with small lumen : outer fibrous coat, thick middle muscular coat having 3 sublayers ; lining epithelium-pseudo-stratified columnar, tall cells bear non-motile cilia. Lumen may contain bunches of spermatozoa.

Seminal Vesicle (Fig. 75)

(i) Outer fibrous coat, (ii) Middle muscular coat having two sublayers, (iii) Mucous coat shows profuse branching and anastomosis giving it a honeycombed appearance, lining epithelium pseudostratified columnar.

Prostate (Fig. 77)

Fibro-muscular capsule and septa. Follicles with wide lumen, some showing infoldings of the epithelium embedded in the dense fibromuscular stroma, and lined by pseudo-stratified columnar epithelium.

Ovary (Fig. 78)

Shows outer cortex and inner medulla. Cortex contains ovarian follicles in different stages of development and regression; corpus luteum may be seen. Note the oocytes in the centre, with zona pellucida.

Uterine Tube (Fig. 80)

A tubular structure having 3 coats; the mucous coat shows folds and numerous branching—lining epithelium simple columnar partly ciliated, and partly secretory.

Uterus (Fig. 81)

Very thick muscular coat; mucosa lined by simple columnar epithelium partly ciliated and contains many simple tubular glands.

Uterine glands: (a) Straight in follicular phase; (b) Cork-Screw type in luteal phase; in L.S. they give a saw-toothed appearance and the cells are filled with secretion.

Vagina (Fig. 82)

A tubular structure with folded walls lined by stratified squamous epithelium non-keratinised. Absence of muscularis mucosae differentiates it from oesophagus.

Cornea (Fig. 83)

Identified by (i) stratified squamous epithelium non-keratinised having 5 layers of cells. (ii) Thick substantia propria.

Retina (Fig. 84)

Mainly identified by layers of rods and cones, closely packed nuclei of outer and inner nuclear layers and single layer of large nuclei of ganglionic cell layer.

18 Viva Questions

Cell

1. What is a cell? Name the smallest and the largest cell in human body.

2. What are organelles? Enumerate them and mention one function of each.

3. What organelles are concerned with autolytic changes in the cell body?

4. What is the number of chromosomes in (i) somatic cell, (ii) ovum?

5. What is the ultra structure of cell membrane?

Epithelium

1. What is epithelium? How do you classify them?

2. Enumerate the various simple epithelia? Why the pseudostratified columnar epithelium is classified as simple epithelium?

3. What is transitional epithelium? Where is it distributed?

4. Give the distribution of non-keratinised stratified squamous epithelium.

5. What is the histological and functional differences between cilia and microvilli?

6. What is basal lamina? How does it differ from basement membrane?

7. Enumerate different mechanisms by which cells are attached to one another.

8. What are desmosomes?

Glands

1. What is a gland? What are endocrine and exocrine glands?

2. Classify glands according to the mechanism of secretion?

3. What are the different types of exocrine glands? Give one example of each.

4. Classify following glands (i) according to mechanism of

secretion and (ii) in respect to duct system—sebaceous gland, sweat gland, mammary gland and parotid gland.

5. What is mucous membrane ?

Connective Tissue

1. Name the fibres of connective tissue.
2. What are reticular fibres and where are they found ? In what way collagen fibres differ form elastic fibres ?
3. Enumerate the different connective tissue cells. What are the features of fat cells and plasma cells, and what are their functions ?
4. What are the functions of mast cells, fibroblasts and macrophages (Phagocytes) ?

Cartilage

1. How would you say a tissue to be cartilage by only one finding ? What are the types of cartilages ?
2. Why cartilage capsule takes a deep basic stain ? Ans. The capsule is most recently formed matrix and has high concentration of acid mucopolysaccharide.
3. In hyaline cartilage collagen fibres are not seen under L M, why ?
4. How the nutrition of catrilage is derived ?

Bone

1. What is periosteum ? What are its two layers ?
2. What are the microscopic features of compact bone ?
3. What lies in the (i) Haversian canal, (ii) Lacunae, (iii) Canaliculi ?
4. What is the difference between osteoblast and osteocyte ?
5. What is osteoclast ? From where is it derived ?
6. Define bone marrow. What are its two types ?
7. What is the structure of red bone marrow, and what are its functions ?
8. What do you mean by marrow cells ?
9. What are the methods of bone development ?
10. What is epiphysis, diaphysis and epiphyseal cartilage ?
11. Describe the blood supply of Long bones.

Blood

1. What are the features of Lymphocyte ? How do you classify it immunologically ?

Muscle

1. Classify muscle and mention most important differences.
2. Why there are dark and light bands in skeletal muscle fibre.
3. What are myofilaments ? What is a sarcomere ?
4. Mention mechanism of muscle contraction in skeletal muscle.
5. What are (i) myoepithelial cells and (ii) intercalated discs ?

Nervous System

1. Define neuron ; classify them according to number of processes.
2. What is myelin sheath ? What is special stain for it ?
3. What cells form myelin in PNS and CNS ? What are nodes of Ranvier ?
4. Enumerate important features of T. S. of a nerve (nerve trunk).
5. What is ganglia ? Classify them.
6. What are neuroglial cells ? Mention their functions.
7. Enumerate sensory end organs. Give the structure of motor end plate. What is a synapse ?
8. Where do you find (i) the largest nerve cell, (ii) Purkinje cell, (iii) Pyramidal cell.
9. Which horn of the spinal cord is sensory and which are motor ?
10. What fibres arise from the lateral horn of the spinal cord ?
11. What are Clarke's column cells and what fibres arise from it ?
12. What is the lining of central canal of spinal cord ?
13. What is isocortex and allocortex ?

Cardiovascular System

1. What is a sinusoid ? How does it differ from capillaries ?
2. What are two different types of capillaries ?
3. What arterial tube is concerned directly in the maintenance of capillary bed ?
4. How an arteriole differs from a venule ? Ans. In arteriole the tunica media contains only smooth muscle, whereas in a venule it contains collagen fibres.
5. What is the main difference between a muscular and an elastic artery, and how both differ from a medium sized vein ?
6. What is the function of internal elastic lamina ?

Lymphoid Tissue

1. Define lymphoid tissue.

2. What is epithelio-lymphoid tissue ? Ans. Lymphoid tissue in relation to epithelium (particularly associated with G.I.T.) is termed epithelio-lymphoid tissue. It includes thymus, tonsils, and lymphoid tissue in appendix and large intestine including the agregated lymph nodules of ileum (Peyer's patches).

3. What are primary and secondary lymph nodules ?

4. What are the main points of differentiation among lymph node, spleen, thymus and tonsil ?

5. Mention splenic circulation in brief.

6. What are two fundamental cell types in thymus ? Where do you find Hassall's corpuscle and what is its structure ?

Endocrine Glands

1. What are the cell types in Pars distalis ?

2. What is pituitary portal system ? What is the nerve supply of Pars Nervosa ? What is a pituicyte ?

3. What is the lining cell of thyroid follicle ? Mention phasic variation in the shape and size of follicular cells.

4. What is the function of para-follicular cells ?

5. What cell types are found in para-thyroid gland ? What cell is resopnsible for the secretion of parathormone ?

6. What is chromaffin reaction ? What is the peculiarity of the nerve supply of suprarenal medulla ?

7. What is the arrangement of cells in different zones of adrenal cortex and what are their secretions ?

8. What do you understand by foetal cortex ?

9. Name the glands which work both as an exocrine and endocrine glands.

Integument

1. What is the lining of skin ? What is the structure of sweat and sebaceous glands.

2. What is hair follicle ? What is melanocyte?

3. How would you say histologically whether the mammary gland is lactating or resting ?

Respiratory System

1. Eumerate the locations where taste buds are present ?

Ans. Taste buds are present in tongue, inferior surface of soft palate, palatoglossal arches, posterior surface of epiglottis and the posterior wall of the oropharynx.

2. What is the lining epithelium of epiglottis? Whay is it thicker on its posterior surface?

3. What is trachealis muscle? How does the cartilage of trachea differ from that of intrapulmonary bronchi?

4. Enumerate changes in the respiratory epitheilum from trachea to alveoli.

5. What are: (i) dust cells and (ii) alveolar pores?

6. What separates the air of the alveoli from blood in the capillaries?

Digestive System

1. What parts of digestive tube are lined by stratified squamous epithelium?

2. Define lingual papillae? What are different types and with whom taste buds are associated? Mention types of cells in taste bud.

3. What is peculiarity about the musculature of oesophagus?
4. How would you differentiate oesophagus from vagina?
5. How does fundic and pyloric glands differ?
6. What is a villus? Describe in brief its structure.
7. What are: (i) Goblet cells and (ii) Argentaffine cells?
8. What are the main points of differentiation in the different parts of small intestine?

9. What cell types are present in submucosal glands of duodenum?

10. What are Peyer's patches?
11. How does colon & caecum differ from appendix?
12. What are zymogen granules?

Ans. They are inactive precursor of the enzyme.

13. What is the structure of parotid gland? How does it differ from submandibular salivary gland?

14. Comment in brief about the duct system of salivary glands.
15. What is a basket cell?
16. How does pancreas differ from serous salivary gland?
17. What are the cell types in islet of Langerhan's?
18. What is the most recent view about the structure of liver?
19. Mention in brief how the blood supply to liver is carried out?

20. How does the mucosa of gall bladder differ from seminal vesicle?

Urinary Sysetm

1. What is uriniferous tubule ? What are its parts ? Why cortex looks granular, but modulla striated ?

2. What are the different parts of nephron and where are they located ?

3. What are (i) podocyte, (ii) juxtaglomerular apparatus ?

4. What forms the filteration barrier in the glomerulus ?

5. What are the histological differences between proximal and distal convoluted tubules ?

6. What are differences between cortical and juxtamedullary glomeruli ?

7. How do you differentiate between ureter and urinary bladder ? What is trigone ?

8. Mention the epithelium of male and female urethra ?

9. What are intra-epithelial glands ?

Male Reproductive System

1. Mention in brief the structure of a sagittal section of testis.

2. What is the source of primordial germ cells ?

3. What is seminiferous tubule ? What are its parts ? At what stage meiosis takes place in spermatogenic cells ?

4. What are the functions of Sertoli cells ? What are interstitial cells of testis ?

5. What are the parts of spermatozoa ?

6. What is stereocilia ?

7. What is the feel of vas deferens ? How would you differentiate vas deferens from epididymis ?

8. Mention in brief the mucosa of seminal vesicle.

9. What are the main features of prostate ? Mention briefly its age changes.

Female Reproductive System

1. What is an ovarian follicle ? Mention its different stages.

2. What is corpus luteum ? How does the corpus luteum of menstruation differs from that of pregnancy ?

3. What is ovarian cycle ?

4. What is decidua ?

5. What is the thickness of endometrium at the end of menstruation and just before its onset ?

6. What changes take place in uterine glands in various phases of uterine cycle ?

7. Describe the structure of uterine tube ?

Special Sense Organs

1. What is the lining of cornea ? What is posterior elastic lamina ? Describe its peripheral part near iris.

2. Enumerate the ten layers of retina.

3. Describe the (i) optic disc and (ii) macula lutea.

4. In which areas of retina (i) only cones are present and (ii) rods are entirely absent.

5. From which cell-layers of retina the fibres of optic nerve arise ?

6. What cells form myelin sheath in optic nerve ?

7. What are maculae and cristae ? What cell types are found in them ? How the two differ in structure ?

8. Describe in brief the organ of Corti.

9. What is secreted by stria vascularis of cochlear duct ? What is the peculiarity of this epithelium ?

Ans. This epithelium contains blood capillaries. All other epithelia are avascular.

INDEX

A Band, 46
Acinus, 118
Adipose tissue, 32
Adrenal (Suprarenal) gland, 84
Anaphase, 13
Aorta, 66
Apocrine secretion, 23
Appendix, 114, 165
Areolar tissue, 31
Artery, 65, 67, 162
Astrocyte, 57
Auerbach's plexus, 105
Auricle, 156
Axon, 52

Basal lamina, 20
Basement membrane, 20
Basilar membrane, 157
Basophil 42
Bellini, duct of, 128
Blood cells, 40-44
Bone, 35-40, 161
Bowmans capsule, 125
Bronchiole, 98
Bronchus, 97-98
Brunner, glands of, 111
Brush border, 20
Bulb of Krause, 59

Capillaries, 68
Cardiovascular system, 65-70
Cartilage, 32, 161
  Elastic, 34
  Fibro, 34
  Hyaline, 33
Cells, 6-12
Centrioles, 9
Cerebellum, 61, 162
Cerebral cortex, 62, 162
Chondrocytes, 33
Choroid plexus, 63
Chromatids, 13
Chromatin, 10
Chromosomes, 11
Cilia, 21
Cochlea, 157
Collagen fibres, 28

Colon, 113, 165
Cones, 154
Connective tissue, 27-44
Cornea, 152, 167
Corpus luteum, 145
Corti, organ of, 158
Crypts of Lieberkuhn, 110
Cytoplasmic inclusions, 9

Dendrite, 53
Dentine, 102
Dermis, 88-89
Digestive system, 101-123
Drum-stick, 11
Duodenum, 111, 165

Ear, 156
Elastic fibres, 28
Enamel, 102
Endometrium, 147
Endoplasmic reticulum, 7
Endothelium, 22
Eosinophil, 42
Epididymis, 136, 166
Epiglottis, 96, 164
Epidermis, 88
Epiphysis, 39
Epithelium, 16-23
  Ciliated columnar, 18
  Columnar, 17
  Cuboidal, 17
  Squamous, 16
  Transitional, 19
Erector pilorum, 90
Erythrocytes, 41
Eye, 152
Eye lids, 156

Fibroblasts, 29
Gall bladder, 122, 166
Glands, 23
  Endocrine, 23, 79
  Exocrine, 23-26
  Mucous, 26
  Serous, 26
Glisson's capsule, 119
Glomerulus, 125

Goblet cells, 24, 96, 110
Golgi complex, 8
Graafian follicle, 144
Granulocyte, 41
Grey matter, 60
Ground substance, 27, 33
Gustatory cells, 104

H band, 47
Haemocytoblast, 44
Hair, 90
Haversian system, 37
Heart, 66
Henle, loop of, 127
Holocrine secretion, 24

I Band, 47
Ileum, 112, 165
Intercalated disc, 49
Intercellular substance, 16, 27
Islet of Langerhan's, 119

Jejunum, 11, 165

Kidney, 124, 166

Lacteal, 71, 110
Lamina propria, 23
Lens, 156
Leucocyte, 41
Liver, 119, 166
Lung, 97, 164
Lymphatic system, 71
Lymphocytes, 42
Lymph node, 72, 163
Lysosomes, 9

Macrophage, 29
Maculae, 157
Malpighian corpuscles, 74, 125
Mammary gland, 92, 163
Marrow, Bone, 37
Mast cell, 29
Myelin sheath, 53
Meissner's corpuscles, 59
Megakaryocyte, 44
Meninges, 63
Menstrual cycle, 148
Merocrine secretion, 23
Metaphase 13, 14
Microglia, 58
Mitochondria, 7
Mitosis, 12
Monocyte, 43
Motor end plate, 59
Mucous cells, 117
Mucous membrane, 23
Muscle, 45-49, 161
  Cardiac, 48
  Skeletal, 46
  Smooth, 45
Muscle spindles, 59
Myeloblast, 44
Myofibril, 45
Myometrium, 147

Nerve endings, 58
Nerve fibres, 53
Nervous tissue, 50-64
Neurofibrils, 52
Neuroglia, 56-58
Neurons, 50
Neutrophil, 41
Nissl's bodies, 52
Nodes of Ranvier, 53
Nuclear membrane, 10
Nucleoli, 10
Nucleus, 9

Odontoblasts, 102-103
Oesophagus, 106, 164
Oligodendrocytes, 57
Oocyte, 143
Oogenesis, 142
Organelles, 7
Osteoblast, 35-36
Osteoclast, 35-36
Osteocyte, 35-36
Osteone, 37
Ovary, 142, 167
Oxyntic cell, 108

Pacinian Corpuscles, 59
Palatine tonsil, 78, 163
Pancreas, 118, 165
Paneth cell, 110
Parathyroid, 84, 164
Parotid gland, 116, 165

Pars distalis, 79
  Intermedia, 81
  Nervosa, 81
  Tuberalis, 81
Peptic cell, 108
Perichondrium, 33
Periosteum, 36
Peyer's patches, 112
Piamater, 63
Pituitary, 79, 163
Platelets, 40, 43
Plasmalemma, 6
Podocytes, 125
Portal canals, 120
Prophase, 13, 14
Prostate, 138, 167
Pulp cavity, 102, 103
Purkinje cell, 61
Pyramidal cells, 52, 62

Rectum, 115
Respiratory system, 95
Reticular fibres, 29
Reticular tissue, 32
Reticulo-endothelial system, 32
Retina, 153, 167
Ribosomes, 7
Rods, 154
Rugae, 107, 131

Salivary glands, 115, 165
Sarcolemma, 45, 46
Sarcomere, 47
Sarcoplasm, 45, 47
Satellite cells, 56
Schwann cells, 53, 54
Sebaceous gland, 92
Serous crescents, 117
Seminal vesicle, 138, 167
Serous cells, 116
Serous membrane, 32
Sertoli cell, 135
Sex-chromatin, 11
Sinusoid, 68
Skin, 88, 163
Small intestine, 107, 165
Spermatogenesis, 134
Spermatozoa, 135
Spinal cord, 60, 162
Spleen, 73, 163
Stomach, Cardiac, 107, 108
  Fundic, 107, 108, 165
  Pyloric, 109, 165
Stratum basale, 88
  Compactum, 148
  Germinativum, 88
  Granulosum, 88
  Lucidum, 88
  Spinosum, 88
Striated border, 20
Sublingual gland, 118
Submandibular gland, 117, 165
Submucous coat, 105
Suprarenal gland, 84, 164
Sweat gland, 91
Synapse, 58

Taste buds, 104
Tectorial membrane, 159
Testis, 132, 166
Thymus, 76, 163
Thyroid, 82, 164
Tissues, 15
Tongue, 103, 164
Teeth, 101
Trachea, 96, 164
Telophase, 13, 14

Ureter, 130, 166
Urethra, 131
Urinary bladder, 130, 166
Urinary system, 124
Uterine tube, 146, 167
Uterus, 147, 167

Vagina, 150, 167
Vas deferens, 136, 166
Vein, 69, 162
Villi, 110
Volkman's canal, 37

White matter, 60

Z line (disc) 47
Zona pelucida, 143

OUR MEDICAL BOOKS

MANUAL OF PREVENTIVE AND SOCIAL MEDICINE Rs. 35.00
(For Medical and Public Health Students)
By R.N. Ghosh, *M.B., D.T.M.*, (Cal.), *D.P.H.* (London)

DISEASES OF THE EAR, NOSE & THROAT Rs. 50.00
(Including Instruments and X-Rays)
By B.K. Roychaudhuri, *M.B.B.S., D.L.0.* (Cal.), *M.S.* (A.I.M.S.)

CLINICAL METHODS IN EAR, NOSE & THROAT Rs. 12.50
By K.K. Sharan, *B.Sc., M.B.B.S* (Pat.), *D.0.* (Pat.),
M.S. (E.N.T.), *M.S.* (Eye)

A GUIDE TO MEDICAL REPRESENTATIVE Rs. 10.00
(A Hand Book for Medical Representatives
Pharmacists, Nurses and Hospital Pharmacists)
First Edition, 1984 Octavo Medium
by M. Pal, Ph.D., Head of the Department of
Pharmacy, Jadavpur University, Calcutta.